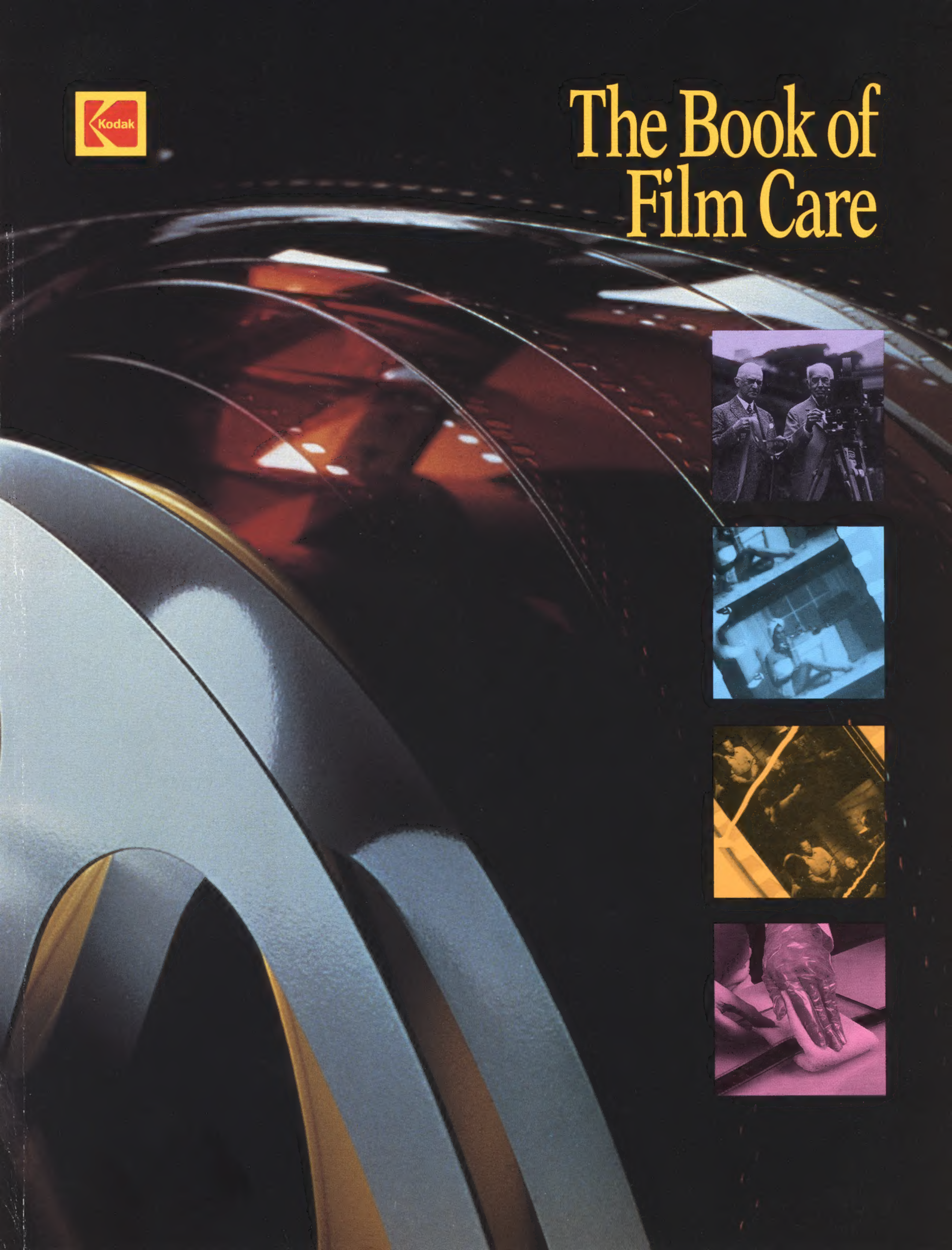
The Book of Film Care



The Book of Film Care

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CHAPTER 1

Introduction and History

For Whom This Book Was Written!

This book is for the worldwide community that has made, or wishes to make, film a part of everyday life.

You may be a projectionist, an audio-visual aide, an archivist with a precious investment in cellulose-nitrate-base films of historical importance, a film director, a film studies professor who needs to know more about the technology at the physical base of this creative art, a training specialist, a scientist who uses film in research, a laboratory owner, a manager, a technician, a librarian who has just begun working with films, a documentary filmmaker, a theatrical film distributor, a theater owner, or a parent who turns the family room into a theater on birthdays.

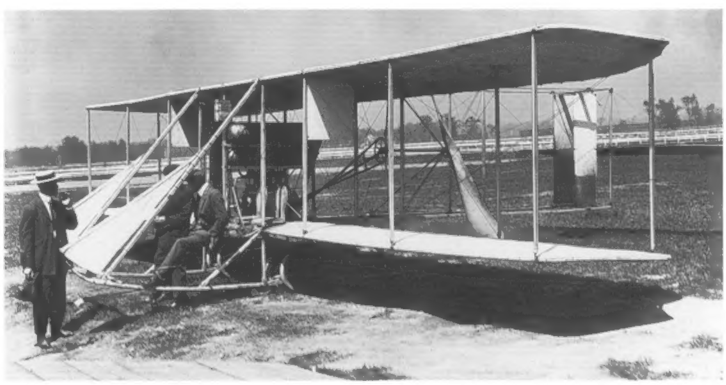
All of you have one thing in common: you expose, process, store, handle, project, or repair films. The films are black and white or color; any format, 8 mm, 16 mm, 35 mm, or 70 mm; current or historically valuable films on cellulose-nitrate base, cellulose-acetate or triacetate base or on ESTAR Base. You may not know about the classification, but you should know how to care for your films for maximum life expectancy so that they always look good on the screen.

If you use film in any active way, this book is for you. It's up to date, complete, and as clear as a sometimes complicated subject allows. It should be very useful and, we hope, interesting.

Photographs and motion pictures are triumphs of human curiosity, inventiveness, and persistence. They are based on centuries of slow, then increasingly rapid, gathering of information and insights on technical solutions to complex problems. Their evolution is marked by triumphs of cooperation across national lines.

Today, in ever-increasing numbers, photographs and films make up a gigantic and priceless visual record, not only in official communication centers and archives but in the closets, attics, and trunks of millions of homes, schools, churches, and shops. Captured in silver and color dyes of film are events, personalities, emotions and attitudes that are a vital part of the modern human psyche and memory.

Daguerreotypes of Lincoln may couple in our minds with his Gettysburg Address. For most of us, much of our knowledge of Hitler, Gandhi, Churchill, DeGaulle, Hirohito, Mao, Pope John XXIII, or Babe Ruth



depends on film. Fred Astaire's dances, Disney and Stokowski's *Fantasia,* and classics like *Gone With the Wind, The Sound of Music, Close Encounters of the Third Kind,* and more recent films that will be preserved for future generations, are a part of world culture. For most of us, only film brings us in touch with the Congo and Amazon, the Andes and Himalayas, earthquakes and tidal waves, the moon and the ocean floor. On film, our master teachers can take us into submicroscopic worlds and into the languages of our many-tongued world.

Yes, you are truly part of a worldwide partnership that begins with those who make precision film and equipment, to those who use film creatively, and to those who process, store, and project it. All who work with film are the vital links who don't want to break the chain in projection or storage rooms when it's their turn to pass on the message.

Figure 1

Why Did We Choose to Write It?

Kodak manufactures film to tolerances of millionths of an inch and controls chemical composition to parts of a million, and they continue to improve. That's why your films are as reliable as they are, but Kodak needs you to do your part. This book is a tool to help you get the best possible results from films. We are sharing our knowledge of up-to-date theory and practice. Hopefully, what you read here will benefit you and others with whom you have contact. And, since no single book has all the answers, we will refer you to other helpful publications and to services that supplement ours.

Poorly handled or damaged films (**Figure 2**) are like scratched, warped, and dirty phonograph records or CDs that make glorious music sound terrible. We hope to help you prevent similar disasters in dealing with your films. They are among the most sophisticated of human products, so they need to be treated with informed care.

Figure 2

Historical Background–Film, Photography, and Motion-Picture Cameras

Motion pictures and still photographs are closely linked historically and technically. As the pioneer photographers (**Figure 3**) of the early 1800s sought exact visual records of the world, they had to sacrifice motion, color, and sound in the scenes before the camera's eye. Their photographs were static, silent, and rendered in black and white and grays. Very long exposures left moving objects registered as smears between sharply etched outlines of cathedrals or along cobbled streets.

But photographers soon learned how to *stop* things in motion. Some part of a complex movement was recorded, but it remained inert.

From infancy, we are innately curious about moving things and how they act on our perceptions. As children we saw toy tops and spinning disks mix colors in our eyes. Colors, or really their opposites, remained briefly in the mind's eye after they were gone. A disk with a goldfish on one side and a bowl on the other could be spun on a string and, miraculously, the goldfish appeared to be in the bowl.

Figure 3

An important fact about the human eye and brain—persistence of vision—explains these experiences. The eye continues to *see* things for a moment after they have, in fact, disappeared.

If we could somehow divide continuous motion into separate still photographs and then present sequential photographs quickly to our eyes, we would sense an image that seemed to move. For example, if a sequence of individual drawings of a rocket going into space could be attached at one edge and then riffled, we would see each slightly different picture briefly, and that would give us a life-like illusion of that shattering experience. (By riffling them in the opposite direction, we would see the rocket land backwards.) Another way of riffling the pictures is to place them in a wheel and view them through slits. Again, they will seem to move.

About three centuries ago, lanterns also produced magic. Candlelight or oil lamps in the days before Thomas Edison, shining through more or less transparent drawings, projected pictures on a wall (**Figure 4**). That was a bit of magic, even though no motion was involved.

Again, going back a bit in history, it had been observed that silver specks in conjunction with organic materials turned dark when exposed to light. If that light came from some recognizable pattern, the shape was recorded in the darkening silver which, unfortunately, kept on darkening until the precious pattern had disappeared in overall black. To *stop* the pattern from going black, took a bit of doing. When that was accomplished, these first *photographs* still could not be duplicated.

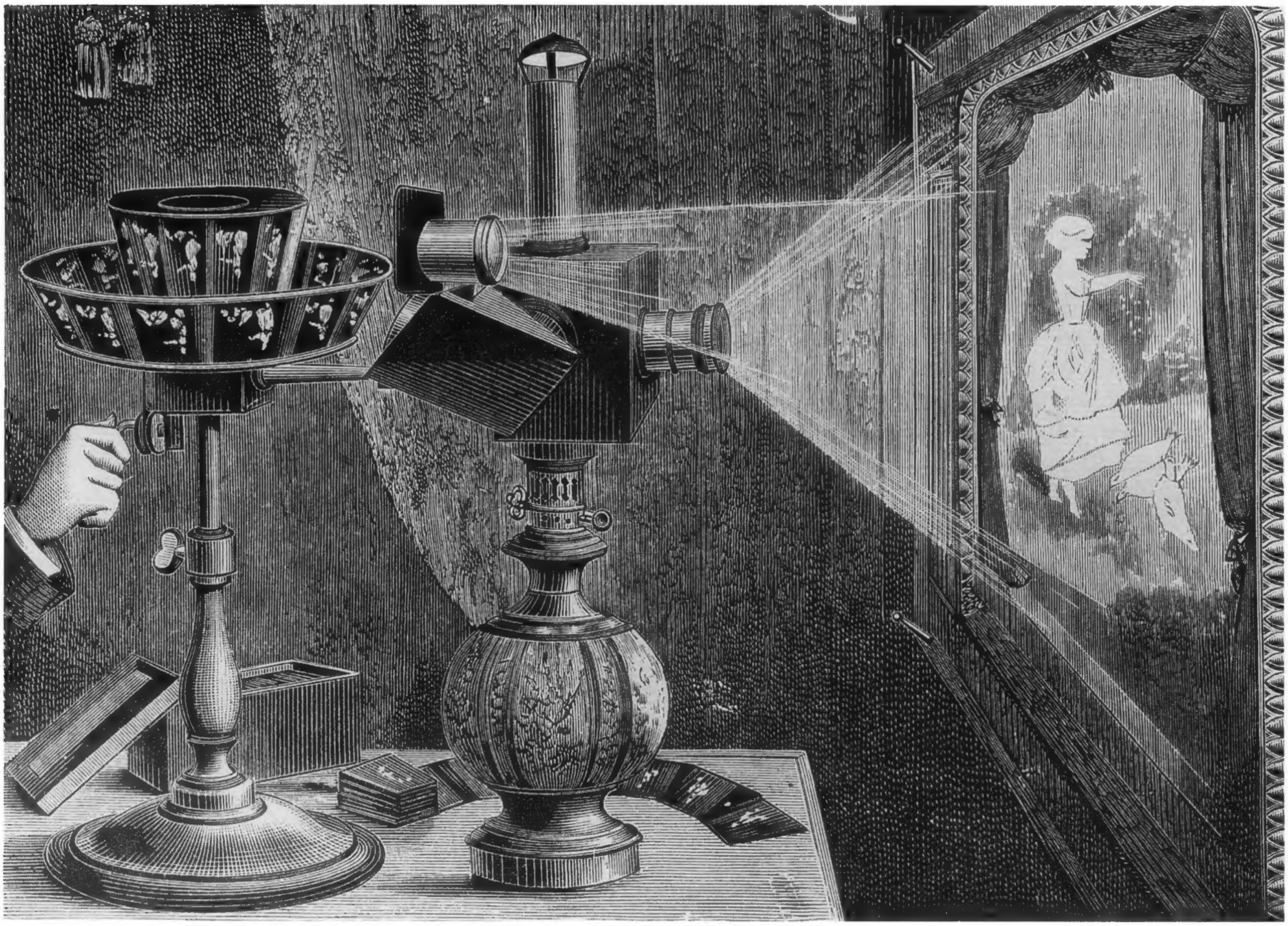


Figure 4

Film

Meanwhile, photographers were wrestling with still other problems. The early images were made on metal or glass plates which were inflexible and difficult to work with. The glass, especially, was breakable. A more flexible base was needed.

A paper base coated with light-sensitive emulsion seemed a better answer, at least, within the camera. The only way to have the *film* processed was to send the camera to George Eastman's young company in Rochester, New York, to have the images developed, stripped from the paper, and transferred to glass. However, after considerable research, Eastman invented a flexible photographic film. Improvements to the relative instability and flammability of its cellulose-nitrate base lay ahead, but a vital step toward motion pictures had been taken because this new flexible base material was used both in the camera and projector.

Camera

Cameras today are now so portable that we have to stretch our minds to remember that *camera* is a word for *room,* and that the first cameras were, in fact, darkened rooms with a single small hole in one wall (**Figure 5a**) to let in light.

The ancient Greeks had seen such light invert an image of an outside scene on an inside wall. For generations, artists of the Renaissance, and after, used that detailed image to make accurate drawings. This phenomenon eventually led to the development of the early photographic *camera* (**Figure 5b**)—a box at the back of which the light- (*photo-*) sensitive solution on a glass, metal, paper, or film base recorded the outside image by changing the specks of silver salts coated on that base. Motion-picture cameras needed to advance perforated film past the open lens, stopping many times a second to record individual pictures, ever so slightly changed, of whatever moved before the camera. A positive print of such a film was then pulled through a projector at the same rhythm and speed.

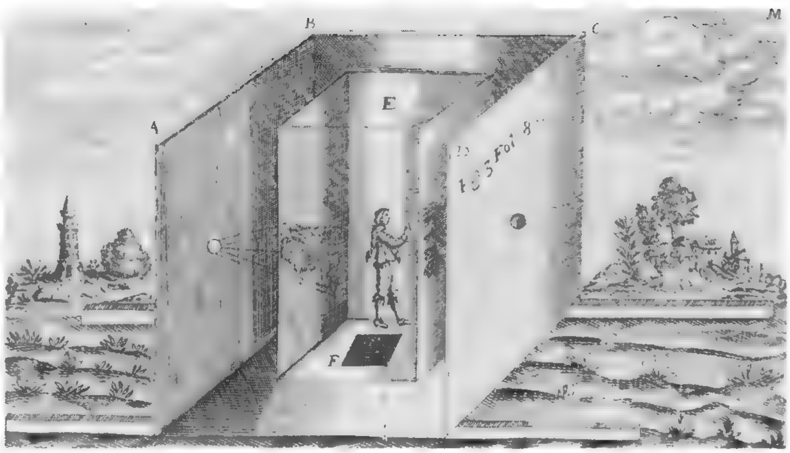


Figure 5a

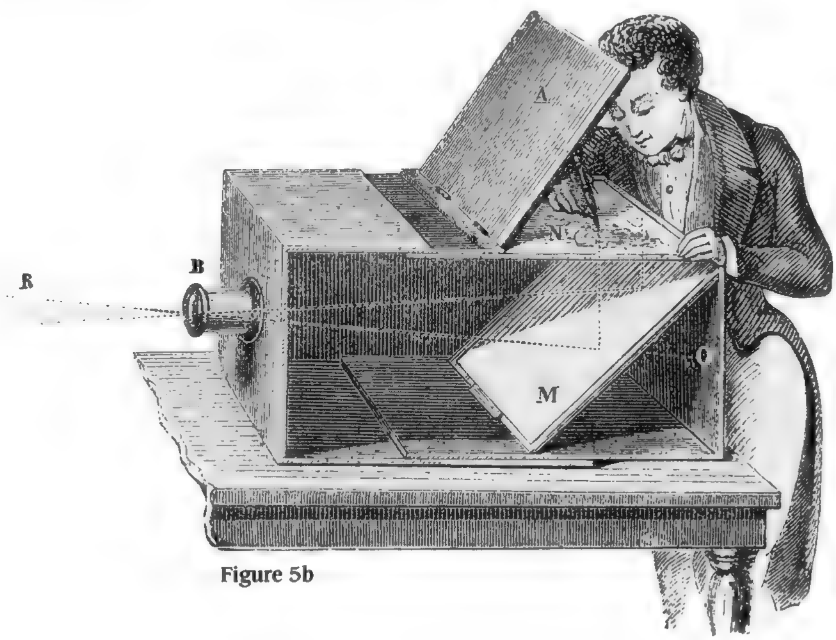


Figure 5b

Edison

Thomas Edison used his talented staff to search patiently along alternative routes to several new technologies. He applied these talents again to develop machines to photograph movement and others to play them back with precision. His first machines were designed for individual viewing, but soon the patient inventor of the electric light bulb would develop projectors that made possible the great darkened theaters into which the curious ones crowded to experience the wonders of the *movies.*

Eastman and His Company

George Eastman began his research for better ways to produce dry photographic plates in his kitchen and soon made machines that produced them with great regularity. He was methodical and ingenious. He had the business and organizational talents to see his ideas work with growing vigor and, at first, with only six fellow workers. (Kodak Park, Eastman Kodak Company's main manufacturing plant in Rochester, New York, now employs thousands and many more thousands are employed worldwide.)

It was there, on 16 acres (now over 2,000), that Eastman pioneered the manufacturing of high-quality film in great quantities. His requirements then, as now, called for clean air and water, meticulously processed organic materials, carefully controlled chemical reactions, precision coating machines, tons of pure silver, and tanks of dyes. Much of the work must be done in little or no light as the machinery operates night and day to supply the overgrowing need for film.

Along with this need for precision-manufacturing skills is a strong

Figure 6

dedication to research and development. Since 1912, the Research Laboratories at Rochester have grown constantly and now employ more than 2000 scientists, engineers, technicians, and support personnel.

The careers of Thomas Edison and George Eastman (**Figure 6**) became entwined; from this relationship, grew the United States motion-picture industry. It was a fortunate parallelism of dedication to workable new ideas. The mutual respect and responsiveness of these two men who fathered these efforts were sometimes recorded—on film— throughout their long friendship.

But the development of motion-picture technology has involved inventors, scientists, business people, and artists from many countries. At various times, England, France, Italy, Germany, and Japan, among others, have played key roles. The international uses of motion picture helped investments and also challenged motion-picture people everywhere to further progress. We are all truly involved in this worldwide effort and enjoyment. Therefore, we want to share everything of importance that we know about handling these remarkable products to help you make them long lasting and faithful.

All elements essential to motion pictures were established by the late 1880s. Present film technology is the result of a long and patient struggle to solve difficult technical problems. The previous historical information was given because it's important to understand that present film technology only evolved because of the drive of a few. This is no idle historical account, because each of the elements of successful motion pictures challenges us when we store, preserve, or handle films. In addition to the images on them, they are the memory of all this inventiveness in the materials and equipment that make them possible.

What If Film Had Not Been Invented?

It is very difficult today to imagine a world without film, whether it be black-and-white or color-still photographs or silent or sound motion pictures. Even though the electronic media have such a high visibility, there is nothing that will take the place of motion-picture film.

Even a modest survey of the worldwide impact of motion pictures would take at least another book like this, so just a few examples follow. Over half-a-century ago the American novelist John Dos Passos in his trilogy, *U.S.A.*, used newsreels of historical figures and events as part of his fiction. Other modern literature reflects the new techniques of the creative motion picture. For many years now, we have experienced the world's greatest events and cultural shifts through the films used in broadcast television.

The processes of teaching and learning have been offered fundamentally new possibilities through film. Family memories are recorded on film. The records of science, government, and business are miniaturized on film. Motion-picture cameras in the hands of astronauts, or orthopedic specialists studying how athletes run, reveal details that would otherwise be missed. Anthropologists use cameras to study the behavior of people in remote areas; those people were changed forever by the onset of society and technology. Great film artists—actors, directors, animators, writers, and producers—use motion picture to touch some of our deepest emotions. None of this can be envisioned without flexible film of high quality.

CHAPTER 2

Film Today

Film seems to be derived from an old word for *skin*. Skin and film can be mistreated in similar ways:

- Skin can be scratched; so can film.
- Skin can be blistered by chemicals or heat; so can film.
- Skin can be damaged by prolonged exposure to the sun; so can film.
- Skin gets dry and brittle in low humidity and cold; so does film.
- Skin is susceptible to fungus in excessive heat and relative humidity; so is film.
- Skin can be burned; so can film.

But healthy skin and healthy film are strong, flexible, and indispensable. We spend billions on skin care each year and know much about it. Why not consider film the same way? In this section, we will describe briefly what film is and how it is manufactured.

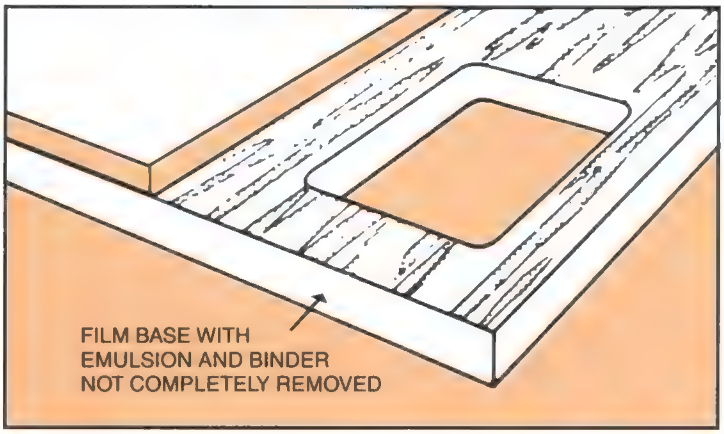


Figure 7

Description of Film

What is motion-picture film? The American National Standards Institute (ANSI) states it as "a THIN flexible strip of plastic, complying with a dimensional standard as defined herein, whose use is specific to the process of manufacturing a motion picture."

That definition leads to about a dozen pages of further definitions about various aspects of motion-picture film. For our purposes, let's take a look at how film is made. You will find that the characteristics built into motion-picture film become very important in exposing, transporting, storing, handling, preserving, and repairing of film, and in the necessities for extended-life storage.

Film Layers

Motion-picture films and other films are made up of layers, and it's the combination of these layers (**Figure 7**) that gives the film its character. It has a supporting layer called the *base*. This base has to be transparent, free from imperfections, chemically stable, insensitive photographically, and resistant to moisture and processing chemicals, while remaining mechanically strong, resistant to tearing, flexible, dimensionally stable, and free from physical distortions.

Fundamentally, film has two main parts; one layer being the base and the other being the *emulsion layer(s)* adhering to the base by means of a binder. Also it may have what is called an *antihalation* layer, which we will discuss later.

Animal/Vegetable/Mineral

The gelatin that carries the light-sensitive material is processed from animal hides and bones. Acetate-base film is made from processed wood pulp and from purified short fibers that cling to cotton seeds after the longer ones are on their way to make clothing. ESTAR Base, used for some EASTMAN Motion Picture Films, is made from petroleum, which is formed from vegetable matter.

Silver, a mineral, is vital to all photography because it's sensitive to light and other radiant energy. Chemicals derived from oil, limestone, and other minerals are also a part of the light-sensitive emulsion.

Film Bases

To manufacture triacetate-base film, the cotton-lint fibers or wood pulp are purified, treated with chemicals and solvents, and mixed and stirred to make a thick liquid from their cellulose—one of nature's building blocks related to sugars and starches. This liquid-cellulose triacetate is cooked, dried into pellets, and put through more chemical and mechanical paces. It is filtered and placed in a partial vacuum to remove trapped air that might cause bubbles.

This clear liquid plastic, *dope,* is squeezed through a very narrow slit onto huge, highly polished wheels where it dries into a thin, uniform layer as the wheel turns. When the solvents in the dope evaporate, a tough, clear, remarkably uniform layer is created. All this is done in extremely clean *white rooms.* The manufacture of ESTAR Base (polyester) basically follows that of triacetate-base film. However, ESTAR Base is chemically constituted in a somewhat different way—principally different is the absence of solvents and the method by which it is formed into a transparent web.

Now, let's explore further the nature of motion-picture film. The film base makes up the bulk of the product, but the base alone could never make a single motion picture.

Film Emulsions

The *photographic* part of motion-picture film is the emulsion. And, as noted from ANSI, "A photographic emulsion consists of dispersions of light-sensitive materials in a colloidal medium, usually gelatin, carried as a thin layer(s) on a film base."

How is such a layer manufactured? After the gelatin is made, it is mixed with the light-sensitive silver salts, and then spread uniformly onto the film base, dried, and then cut into the desired width. This description is over-simplified but is basic to the method used.

Silver in Silver Screen

The *silver screen* usually stands for the whole, sometimes the glamorous, world of motion pictures. We probably don't understand the silver-laden emulsion or its role in the making of pictures. Silver bullion, almost 100 percent pure, is the starting point. Dissolved in nitric acid, it is stirred, cooled, and finally made into pure silver-nitrate crystals.

These crystals are dissolved and mixed with gelatin and other chemicals to form silver-halide grains. The size and degree of light sensitivity of these grains set the speed or the amount of light required to register an image and the graininess that we see on the silver screen. Under the scanning-electron microscope, grain appears as eight-surface solid cubes or irregularly shaped pebbles.

The faster the film, the larger the grain, which will lead to the so-called *grainy* look. Kodak scientists have discovered that if the grain shape is changed to be more flat, the crystals intercept more light, but the total volume of silver does not change, allowing for an increase in speed with fine grain.

KODAK T-GRAIN® Emulsion is the common term for this type of grain because of its flat tablet-like appearance. In 1991, Motion Picture and Television Imaging of Eastman Kodak Company received an Oscar from the Academy of Motion Picture Arts and Sciences for incorporating T-GRAIN Emulsion technology into motion-picture films.

By incorporating T-GRAIN Emulsion into film structures, Kodak can achieve, in addition to speed and grain, overall improvements in film quality. Not all T-GRAIN Emulsions perform better than conventional grain, resulting in a combination or only a conventional grain used in some films.

All grains are evenly distributed throughout the gelatin which is thinly spread on the base—a few 100,000ths of an inch thick, within tolerances of 1/1,000,000th of an inch. For camera films, the light-sensitive, grain-bearing emulsion must be applied to the base in total darkness.

In color print film, three dye layers (**Figure 8**) register various parts of the color, on top of each other, for the full-color effect—one layer each for the cyan, magenta, and yellow dyes. Gelatin, then, is a vehicle, much as water or oil is for the painter.

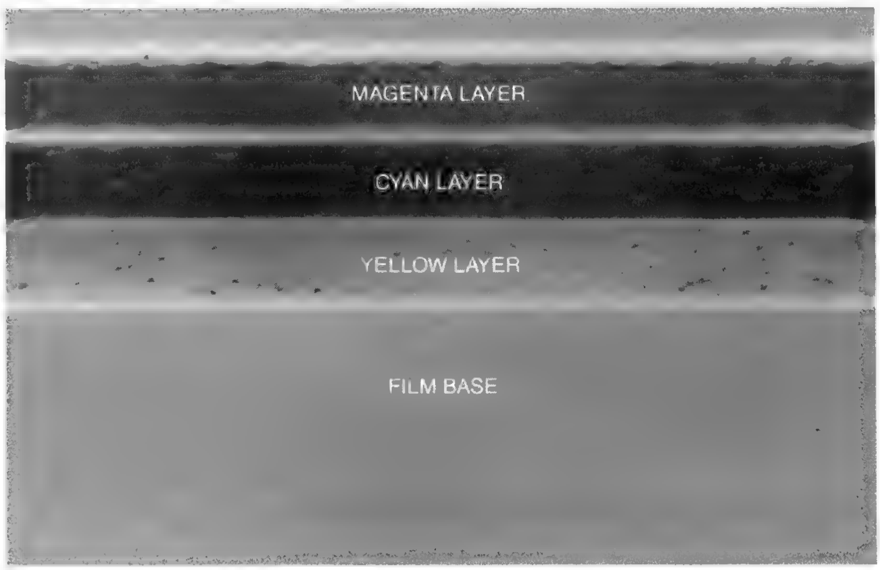


Figure 8

One final layer is sometimes added to the film base, between the emulsion and the base—or on the back of the base in the form of rem-jet backing. This additional layer is usually found on camera films and on a few laboratory films for antihalation protection. Without this protection, as light bounces about during exposure, reflections create halos around some of the brighter areas, resulting in less sharp images.

Film Finishing

Precision slitting and accurate perforating according to detailed specifications are the final steps in the manufacturing process. Uniformity of film width is as important as uniformity of thickness. The exacting placement of perforations, along one or both edges, is essential to control the speed and tracking of film through the camera and projector.

Other Considerations

The film base supports the emulsion layer(s). After exposure, the silver halides in either black-and-white or color films affected by light, are developed chemically, and the unexposed silver halides are removed by the fixer (hypo). In color films, after a bleach bath, the remaining silver is removed, retaining only the colored dyes. The gelatin layer is hardly indestructible, but it's made to withstand various assaults. Moderate heat, by itself, after processing, doesn't affect it very much, but heat with high relative humidity can degrade it into a sticky mess, and the acids, either liquid or airborne, can also cause havoc.

The finished film goes into cameras all over the world to record, react, and explain human experience. When seen by the motion-picture camera, usually at the rate of 24 frames per second, the silver salts undergo an invisible change that stores a *latent image,* where light falls upon it, until the film is developed.

Even more impressive than working in the dark to extremely precise tolerances are the sanitary conditions required during manufacturing. No airborne impurities, light, or any other radiant energy must disturb the high sensitivity of raw film. The air in these manufacturing rooms is filtered and changed many times an hour. Specially laundered lint-free white uniforms are worn. Certain cosmetics and medications that might interact chemically with the film are forbidden. Everything is vacuumed and scrubbed at regular intervals. Daily samples of raw materials and film are tested against carefully determined standards, including extremes of heat and relative humidity. Motion-picture film may never again be in a setting so carefully controlled.

Safety Base Film

The first EASTMAN Motion Picture Film Base provided the necessary flexibility but wasn't without some inherent problems. This base needed to be as clear as possible and strong enough to carry its image layers through cameras, projectors, shipping reels, and processing machines. The first film base was good enough to accomplish this need and remain active for well over half a century. This base was cellulose nitrate.

Nitrogen-based compounds, being vital to life on this planet and a contributor to agriculture, processing, and manufacturing, were naturally among the materials considered when a flexible film base for photographic emulsions was sought over a century ago. The base was excellent for flexibility, strength, and clarity, but it was chemically related to gun cotton, making it unstable and highly flammable. A search for a safer film, especially for amateur use, had begun.

By 1912, George Eastman had developed a commercially acceptable cellulose-acetate safety film for amateur use. Still, cellulose nitrate would continue in professional use until 1949, when all Kodak film products began to be produced with cellulose-acetate base. By 1951, cellulose nitrate was no longer used in production in the United States, and an improved cellulose triacetate, that provided the required strength and dimensional stability for professional products, became the standard.

The latest entrant in the progress towards a satisfactory film base is a polyester material known as ESTAR Base. Both cellulose-triacetate and ESTAR Base Films are true safety films because they are *slow burning,* as carefully defined by the International Organization for Standardization (ISO 543) or by the American National Standards Institute (ANSI PH1.25, 1989).

A copy of this standard is available from the American National Standards Institute, 1430 Broadway, New York, NY 10018. Telephone (212) 642-4900. From our knowledge, all motion-picture films manufactured in the United States since 1949, and including the manufacture of all 16 mm and 8 mm motion-picture films, have been coated on safety base. However, there may have been instances where 35 mm nitrate film was reslit to 16 mm.

While safety is an important characteristic of motion-picture film, most important is its ability to meet other conditions that subject the film to various stresses that act on its internal structure. For example, a piece of film goes through a camera or projector (**Figure 9**), it is pulled (stretched) and pushed (compressed), and unless it is abused, keeps performing as expected. Film must be flexible but sturdy.

Mechanical Properties

The following is a list of desirable mechanical properties for motion-picture-base film:

Strength (tensile strength). A measure of the pulling or longitudinal stress that the film can bear before breaking.

Toughness. A measure of the resistance to stress and stretch before breaking.

Tear strength. Resistance to tearing in initiation and propagation.

Stiffness. Rigidity (within its overall flexibility).

Yield strength. A measure of the force the film can sustain before permanent deformation.

These inherent physical properties must be supplemented by dimensional stability and resistance to moisture, among other qualities. Film emulsion swells during processing, shrinks during drying, and the emulsion and base continue to shrink at a decreasing rate throughout their life. These changes are greater for acetate-base films.

Figure 9

Dimensional shifts in film can be *temporary* (reversible) or *permanent* (irreversible). Temporary changes are caused by modification in relative humidity and temperature. In acetate film, permanent shrinkage is caused by the loss of residual solvents and by the gradual elimination of strains introduced during manufacture and processing. ESTAR Base Film has no residual solvents or plasticizer. Dimensional stability in polyester is due to its biaxial orientation at manufacture and is also partly due to less moisture susceptibility. However, at least some permanent shrinkage occurs in all films during processing and during aging of the raw stock and of the processed film.

Comparisons of Triacetate and ESTAR Base Films

The two primary types of bases used today are triacetate and polyester. The emulsions on any base are open to the same abuses. The two different bases themselves do have an influence on the amount of physical damage a film can take before it becomes unusable.

Compared to triacetate-base film, ESTAR Base is tougher, less brittle, and exhibits greater strength and tear resistance. It can be made thinner than triacetate, which makes for smaller rolls or more film on the same diameter roll. Although it is generally used in a thinner form than acetate, physical properties of ESTAR Base make it as stiff and strong as the thicker acetate base. It's also somewhat more moisture resistant and that adds to its dimensional stability. Changes in the emulsion don't cause large changes in length or width. The qualities of increased strength and toughness make ESTAR Base very good for user-centered operations such as film-lending libraries.

The amount of curl that film takes is another point of comparison. Film in roll form maintains flatness across its width, but it curves along its length, the inner surface being under compression and the outer under tension. If wound around a core, this temporary curvature is called *core-set;* if freely looped, it is called *loop-set.* ESTAR Base Film takes on core-set more slowly than acetate, but it also recovers more slowly. Generally, you should store film on *large diameter cores* and *wound emulsion-in.*

ESTAR is stronger than acetate and can be made thinner. However, some drawbacks of thin film include possible unpredictable behavior in self-threading mechanisms and a tendency to wander within the thread path, especially when used in equipment designed to handle film of greater thicknesses. Firm but gentle film guides, gates, sprockets, and other mechanical-handling apparatus are essential with thinner film. In screen-image terms, the effect of heat on thinner bases can cause more difficulty in maintaining acceptable image quality because of focus drift. There is some evidence that ESTAR Base is superior for scratch or abrasion resistance.

A big drawback for the polyester support is in splicing. Familiar cement-splicing techniques that work on acetate cannot be used on ESTAR Base. You can use organic solvents to splice cellulose-triacetate-base films, but heat-fusion techniques that use dielectric heating, ultrasonic energy, or radiant energy are necessary to thermal-weld polyester to polyester. But they can't be used for splicing ESTAR Base to cellulose-triacetate base.

Pressure-sensitive splicing tape is currently the preferred method of splicing polyester-base film to itself, as well as polyester to triacetate. Reliable non-oozing adhesives and flexible-support materials, made expressly for film splicing, assure that splices are not likely to come apart or break during processing or projection. Consistent performance requires that tape splices be applied to both sides of the film.

CHAPTER 3

Storage and Preservation of Motion-Picture Film

Photographic film is affected by relative humidity, temperature, age, light, chemical contaminants in the atmosphere, and, on unprocessed film only—radioactivity. The effects of these conditions vary depending on whether it's in a sealed package, opened but unexposed, or processed. This chapter will address these conditions and recommend proper storage environments.

Faithful attention to storage conditions is mandatory for quality preservation of motion-picture films. Deviations can initiate film degradation and thus cause instability of the silver or dye image. Deviations can also weaken the mechanical properties of the support, delaminate the emulsion layers, or deform or distort the film. The following recommended storage conditions aren't as stringent as one might expect. If quality film preservation is your goal, it's important that these *recommended storage conditions* be maintained.

The two national standards for the specific dialogue of proper film storage and preservation are ANSI IT9.1-1989 and ANSI IT9.11-1992, which define the parameters necessary for proper processing and preservation of film. If preservation of motion-picture films is your goal, you should obtain a copy of each complete standard.

ANSI Standard IT9.1-1989, *Imaging Media (Film)—Silver-Gelatin Type—Specifications for Stability* combines information for safety *cellulose-ester* and *polyester* bases (formally ANSI PH1.28-1984—*Archival Records, Silver-Gelatin Type on Cellulose-Ester Base* and ANSI PH1.41-1984—*Archival Records, Silver-Gelatin Type on Polyester Base).* It applies only to photographic film intended for medium- and long-term records; specifically, it applies to films with a safety cellulose-ester or polyester (polyethylene-terephthalate) support having silver-gelatin emulsions processed to produce a black-and-white image by negative or full-reversal processing.

This standard doesn't include silver images that are altered by treatments such as toning, intensification, or reduction. Nor does it include silver images produced by dry, thermal processing, or by diffusion reversal or partial halide-reversal processing. Also excluded are all types of color images and motion-picture films with magnetic-recording tracks. Films that are processed by a monobath or by a reversal process, which combines developer and fix in one solution, aren't included in this specification; there is insufficient experience with this matter.

Processing for Permanence

We have all heard that "well begun is half done," and it's true for the processing of film. Well begun is starting with the best professional film processing obtainable. When unexposed silver salts in an emulsion are fixed (removed), they are converted to complex silver-thiosulfate compounds. Some of these may be left in the processed film if the fixation and washing that follows aren't thorough. If higher-than-allowed amounts of hypo are left in the film, they will eventually break down and produce a yellow-brown silver sulfide stain in the lighter image area. (Even more startling shifts may occur in color films because dye fading may be quite different from one dye layer to another.) While every black-and-white film type has its own particular processing recommendations, complete fixing and washing generally should be done at temperatures of about 21°C (70°F) or above. Colder temperatures require longer solution-immersion times. Washing is more efficient when you use counter-current washing techniques, but washing time must be long enough to reduce the hypo to the recommended levels of **Figure 10.**

Limits for Thiosulfate Concentration

Film Type	Film Classification	Maximum permissible concentration of thiosulfate ($S_2O_3^-$) (g/m^2)
Radiographic	medium term long term archival	0.100 0.050 0.020
Microfilms	long term archival	0.030 0.014
Other-fine grain (motion picture film)*	archival	0.007
Other-coarse grain	archival	0.020

*In 1991, thiosulfate requirements for motion-picture films were reviewed by the ANSI IT9 committee. Check with ANSI for the latest information on this topic.

Figure 10

For maximum image permanence, additional washing may be needed. If in doubt, you should determine the residual-hypo content. The Methylene Blue Method recommended in ISO 417 or in ANSI PH 4.8-1985 is a worldwide industry standard for making this determination. Thiosulfate concentration limits are listed in ISO 4331 and ISO 4332, which can be obtained from ISO or ANSI. In 1991, the ISO/TC 42 committee met to draft a revision and to combine these two standards. The combined draft for the International Standard is ISO/DIS 10602. The limits are also listed in ANSI IT9.1-1989.

This standard applies to films that have ultrasonic or dielectric splices. The wide variety of materials used for tape splices doesn't permit their inclusion in this specification. Solvent-type splices are also a suspect since they may retain traces of residual solvents containing peroxide, which can pose some risk of oxidative attack on the silver image.

Although lacquers and other coatings may be applied to processed film for fungus and scratch protection, without any known detrimental effect on permanence, the wide variety of possible protective materials doesn't permit their specification as a standard at this time. A protective layer, such as a special lacquer, can be coated onto the base and/or emulsion sides of motion-picture films as a deterrent to light film-surface scratches. If the lacquer becomes scratched, it can be easily removed by running it through a 1-percent sodium-carbonate solution at a temperature of 18°C (65°F), followed by a water rinse. While this was once a common practice, it is felt that improvements in film-transport equipment and film-handling techniques no longer warrant this procedure. More information can be obtained from the Journal of the SMPTE 36:191, February, 1941.

ANSI IT9.1-1989, specifies parameters for the chemical and physical characteristics of photographic material, but you should realize that this, by itself, doesn't ensure that the films will not deteriorate. However, if you follow the specifications, the films will survive for an extended period. In addition to these parameters, it's essential to provide proper storage and protection from hazards. This information is available from ANSI Standard, IT9.11-1992.

ANSI Standard IT9.11-1991, *Imaging Media—Processed Safety Photographic Film—Storage* (proposed replacement standard for PH1.43-1985, *Processed Safety Film—Storage)* deals with the storage conditions, storage facilities, handling, and inspection procedures for processed safety photographic films in rolls and other forms. Also this standard applies to only the storage of safety photographic film (ANSI PH1.25-1989, *Safety Photographic Film, Specifications)* and for medium- and extended-term storage conditions. Nitrate-base films are hazardous and aren't included in this standard. For nitrate-base film, refer to ANSI/NFPA 40-1988, *Storage and Handling of Cellulose Nitrate Motion Picture Film.* (More on nitrate film later.)

Segregate and store films that show signs of degradation away from unaffected films. If you want to save the film, inspect it immediately to evaluate the possible damage. If it's in reasonable condition, carefully clean and recondition the film to the proper humidity, if necessary. Then place it into a clean can, and store it as specified in this chapter. The recommended storage conditions will not rehabilitate the film but will retard further deterioration. If the condition of the film is relatively poor, but manageable, copy it onto fresh film, preferably on polyester base.

Processed safety films that are stored under adverse or unknown storage conditions should be inspected periodically or at least every 2 years to determine whether they show signs of degradation. A quick means of detecting degradation of cellulose-ester safety base is first by a visual check and then by smell of a *vinegar-like* (acetic acid) *odor.* If the odor exists, it's evident that degradation has begun. If in doubt, measure the pH of a gram of film sample in 100 millilitres of distilled water (or 0.1 gram of film in 10 millilitres of distilled water). If the measured pH is less than 5.0, the degradation of cellulose-triacetate film has been initiated. Polyester-base films are significantly less vulnerable to such hydrolytic degradation.

To assure the predicted life expectancy of all safety acetate and polyester films, you can't deviate from the long-term recommended storage conditions. The hydrolytic-degradation reactions of cellulose-triacetate films take place long before any physical degradation signs are noticeable. Please be aware, chemical inertness can't be achieved over the entire life span of any motion-picture film, even under the most stringent storage conditions. However, from the estimations based on mechanical performance, the information recorded on motion-picture film will be maintained, and it can be retrieved or duplicated for its end use, in a given system for many centuries. The following storage temperatures and humidities (**Figure 11**) are recommendations as listed in ANSI IT9.11-1992.

Recommended Relative Humidity and Temperature Conditions for Storage

Film Type	Medium-Term Storage		Extended-Term Storage	
	Relative Humidity Range (%)	Maximum Temperature	Relative Humidity Range (%)	Maximum Temperature
Silver Gelatin	20–50	25°C (77°F)	20–30	21°C (70°F)
Color	20–30	10°C (50°F)	20–30	2°C (36°F)

Figure 11

Based on accelerated testing methods, it's estimated that properly processed and washed black-and-white cellulose-triacetate films, when kept at 21°C (70°F) at a 20- to 30-percent relative humidity, will have a maximum life expectancy rating of 100 years, and polyester-base black-and-white films kept under similar storage conditions will have a maximum life expectancy rating of 500 years. Thus, the support type becomes the limiting factor for the longevity of black-and-white films.

It is important to understand that the life expectancy ratings noted in the previous paragraph do not apply to color films. The storage recommendations for color films are 2°C (36°F) at a 20- to 30-percent relative humidity. There are currently no ANSI specifications on life expectancy of color films or papers. Color dyes are more prone to change than a silver image. It is difficult to determine the life of a usable color image when the three dyes can fade at different rates, causing hue shifts and imbalances in contrast and color perceptions. Thus, the dye fading becomes the limiting factor for a color film. Chapter 7 discusses color and contrast reconstruction.

Current information and updates to standards (ISO, ANSI, or SMPTE documents mentioned in this publication) can be obtained from:

International Organization for Standardization (ISO)
Central Secretariat
1, rue de Varembe
Case postale 56
CH-1211 Geneve 20
Switzerland/Suisse
Telephone 41 22 749 01 11

American National Standards Institute (ANSI)
1430 Broadway
New York, NY 10018
Telephone (212) 642-4900

The Society of Motion Picture and Television Engineers (SMPTE)
595 West Hartsdale Avenue
White Plains, NY 10607
Telephone (914) 761-1100

The stability of processed motion-picture films varies as a function of their storage history. As noted earlier, the ANSI IT9.11 Standard recommends a storage humidity of between 20 to 30 percent for both cellulose-triacetate and polyester-base films for extended-term storage. Evidence has shown that this humidity range will give black-and-white films their best life expectancy when stored at 21°C (70°F) or lower and color films at 2°C (36°F) or lower.

The word *archival,* which means permanent and forever, has been used freely to describe long-term storage. This word is to be deleted from future revisions of ANSI documents. In its place will be a rating for the *Life Expectancy* (LE) of recording materials and associated retrieval systems. A number following the LE symbol is a prediction of the life expectancy in years for which information can be retrieved without significant loss when stored under specified term-storage conditions, e.g., LE-100 indicates that information can be retrieved after 100 years of storage. Check with ANSI or ISO periodically for the most recent motion-picture film-storage recommendations.

Storage Terms

Medium-term storage conditions are suitable for the preservation of recorded information for a minimum of ten years. *Extended-term* storage conditions are suitable for the preservation of recorded information having permanent value.

Storage Variations

The following sections will describe storage variations that may meet your wants and needs. If in doubt, it is important that you read this chapter and strictly adhere to the ANSI/SMPTE standards for the recommended film storage "life expectancy" rating and storage specifications.

General Considerations and Comparisons

Some of the best examples of European medieval clothing were found in the permafrost of Viking communities in Greenland. Mastodon flesh has been preserved thousands of years in frozen Siberian tundra. The widely travelled exhibition of King Tutankhamen's burial-treasure trove (**Figure 12**) illustrates still other instances of remarkable preservation of various materials, including dyes. The climate (cold and dryness) helped.

In contrast, only some of the carved stones survived mold and erosion induced by the tropical heat and wetness of Mayan Yucatan or Angkor Wat in Cambodia. For centuries, our foods have been dried with success, stored at reduced temperatures in the dark, and more recently, quick-frozen to save their flavor and color.

What do these cases have to do with the storage of film? Photographic film, like food or clothing, or ordinary paper records, must be protected against water, mold, chemical, or physical damage. It must also be protected against extremes of relative humidity and heat. The quantity of moisture held by a photographic-film stock reaches an equilibrium determined by its chemical properties and by the relative humidity of the air.

Relative humidity (RH) compares the amount of water vapor in the air with the greatest possible amount that it could hold at the same temperature. If it's carrying half its capacity, its RH is 50 percent and can be measured by simple calibrated humidity indicators. Relative humidity is always a factor in film storage, but it becomes especially bothersome at high temperatures because the moisture-carrying capacity of hot air is greater than that of cold air. Therefore, film is more susceptible to change from *high* temperatures, because it's also most susceptible to attack from moisture. All of us know this from our own experiences in combinations of hot and cold air, wet and dry air.

Figure 12

We all know certain reactions occur faster at higher temperatures—film is no exception—regardless of whether it's raw or processed. Time is also important with temperature and relative humidity closely interwoven.

Storage of Raw Stock

When film reaches an appropriate moisture equilibrium after manufacture, it's carefully put into a film can and sealed with tape. The can is now usually impervious to normal levels of relative humidity, but some cans may rust. Short-term storage in low or high relative humidity isn't immediately threatening so long as the packages of raw film remain sealed.

Cold temperatures are best for slowing the inevitable changes in sensitivity. If raw stock must be kept for periods of up to 3 months, temperatures of 13°C (55°F) or less are appropriate. If raw stock must be kept longer than 3 months, freezing at −18° to −23°C (0° to −10°F) is recommended. After any cold storage, be sure to allow the films to equilibrate slowly to the ambient temperature where it will be used. This is necessary to prevent moisture condensation and spotting. Conditioning time will vary with the thickness of the packages and the temperature and dew point of the outside air. A 100-foot roll of 16 mm can take as little as ½ hour to condition whereas a 1000-foot roll of 35 mm may take up to 3 hours. Do not open the packages if they feel colder than the ambient temperature. Always use films soon after purchasing.

Raw stock must be protected against harmful gases and radiation. Some of the harmful gases are formaldehyde, hydrogen sulfide, hydrogen peroxide, sulfur dioxide, ammonia, coal gas, and automobile-engine exhaust. Also to be avoided are vapors from solvents, mothballs, cleaners, turpentine, mildew or fungus preventives, and mercury. The chemical vapors can attack the photographic emulsion. Some of the vapors may slowly penetrate the tape that seals the film can. You may be shocked at how many of these gases, vapors, and fumes are in your closets or storage rooms.

Some, such as ammonia, formaldehyde, and sulfur dioxide (rotten eggs), are easily recognized by their pungent odors. Of these three, let's look at the one that may be the least familiar, formaldehyde. You may associate this multi-use chemical only with biological specimens. Formaldehyde can be all around us in products, such as the particle board and plywood in walls, cabinets, or furniture and also in some types of insulation and many adhesives and synthetic fibers.

Raw stock must be kept away from excessive heat and water which would make it tacky. The temperature in a closed automobile in the sun can easily register over 55°C (130°F). This somewhat fragile material—film—is especially sensitive until it's exposed and properly processed. An area of particular concern for protecting raw stock is radiation, whether it be an obvious source or ambient. Always process film soon after being exposed to lessen the chance of contamination.

Ambient-Background Radiation (Effects on Raw Stock)

Ambient-gamma radiation is composed of two sources: a low-energy component which arises from the decay of radionuclides and a high-energy component which is the product of the interaction of cosmic rays with the earth's upper atmosphere. The radionuclides responsible for the low-energy photons exist in soil and rock and are carried into earth-derived building materials such as concrete. Lead shielding or storage deep underground may be helpful, but for long-term raw stock storage, radiation will still be a factor. Upon exposure to ambient-background radiation, photographic materials can exhibit an increase in minimum density, a loss in contrast and speed in the toe, and an increase in granularity.

The change in film performance is determined by several factors, such as the film speed and length of time exposed to the radiation before the film is processed. A film with an Exposure Index (EI) of 500 can exhibit about three times the change in performance as a film with an EI of 125. While this effect on a film product isn't immediate, we still suggest exposing and processing the film soon after purchase. We recommend a period of no more than six months from the time of film purchase before exposure and processing, provided it has been kept under specified conditions. Films kept for extended periods beyond six months may be affected, especially the faster films, even if they have been frozen. The only way to determine the specific effect of ambient-background radiation is to make actual tests or measurements by placing a detector in the location where the film is stored. The most obvious clue is the observance of increased granularity, especially in the light areas of the scene.

Known Possible Radiation (Airports)

For the protection of travelers, all domestic airports use electronic devices and X-ray equipment to check passengers and hand-carried luggage. Film can tolerate some X-ray exposure but excessive amounts will result in objectionable fog (increase in base film density) and noticeable grain. This is particularly true for very high-speed films. In the United States, passenger inspection inflicts only very low-level rates of X-rays, which should not perceptibly fog most films (inspection stations can vary in radiation intensity). The effects of X-rays are cumulative, so repeated X-ray inspections can lead to an increase of fog and grain.

Caution: You can avoid this danger to unprocessed film by hand carrying it, including film in cameras, and asking the attendant to visually inspect it, thus bypassing the X-rays.

Foreign Travel

Airport security measures at international and foreign airports can pose a threat to unprocessed film. Not only is there a danger from X-rays, but security and customs agents may open containers of unprocessed film, ruining weeks of work.

The best protection, when travelling abroad, is to write or speak to the airport manager well in advance of your arrival and explain the relevant details of your trip. Give them your arrival time, flight number, and departure time. List the equipment and film you're bringing to your destination. Ask if there are any steps you can take to expedite matters and ensure the safety of the film. Repeat the process before leaving the foreign country.

For international travel, you may find it worthwhile to work with an export company or customs broker. These are private companies that expedite the handling of international shipments and do the paper work involved. Check "Exporters" in the yellow pages of the telephone directory.

Another way to avoid problems is to have the film processed in the country where it was exposed. Eastman Kodak Company can help you find a local laboratory. Just consult one of the offices listed in the back of this book.

General

Throughout this discussion the conditions for motion-picture films used commercially by theater professionals will be described. Also included will be educational and business uses of motion-picture films, where facilities, expected lifetime of the film, and even the training of some of the people handling the film in these settings are quite different. Later, we will treat the problems of handling and storing *nitrate-base* film and the special demands of safety base very long-term storage.

One of the advantages of processed film is that it's no longer light sensitive. But, as we've pointed out earlier, it's subject to inevitable change over time. So some important decisions and preparations must precede any storage.

Decisions involve the length of storage time and the quality standard that needs to be achieved. Preparations include getting the film into the best possible physical and chemical shape and achieving temperature and relative-humidity conditions that will maintain those qualities to expectations, while preserving the film against such other dangers as floods or leaking pipes, fire or hot sun and heating pipes, earthquakes or falling ceilings or shelves.

Here are some basic questions that you must answer in establishing adequate storage conditions:

- How long do I intend to store the film?
- What kind of film is it?
- What standard of preservation am I trying for?
- Will my ordinary storage room suffice?
- If not, what special storage conditions can I afford?

Most films sit more than they run. They sit in containers and also travel great distances while being bounced, heated, and even frozen along the way. When films run, they are expected to be sharp, clean, and to meet all other demands of a first-class presentation. Therefore, storage facilities and the care with which films are handled, both in and out of storage, are crucial. Consider films as if they are live images, and treat them that way. Film is not a dead substance; it's often highly responsive and somewhat sensitive.

Protection Required

In addition to protecting film against the more obvious dangers, you must guard it against high relative humidities (RH) which accelerate the fading of color dyes, damage the gelatin, and promote the growth of mold, as well as the decomposition of safety-acetate base. High RH also speeds shrinkage, doubling the permanent shrinkage in some films when it goes from 60 to 90 percent for extended periods. High RH can also cause *ferrotyping* (**Figure 13**), the formation of glossy marks on the emulsion, or even sticking when the film emulsion is wound in contact with the base.

Low RH results in temporary film curl and decreased flexibility. Fortunately, some low RH effects can be reversed when humidity rises. Very low RH in very long-term film storage can cause the film to become brittle and crack or break during handling. Negatives, from which prints are to be made, stored at low RH may produce static marks on the print stock during printing.

Various film distortions can result from storing motion-picture film rolls at any relative humidity much different from the equilibrium RH (about 50 percent) of the film. Film edges are like import/export harbors for the exchange of moisture. When rolls in equilibrium, with air at 50 percent, are stored at 20-percent RH for extended periods, they may buckle because the edges lose moisture faster than the interior of the roll. On the other hand, fluted or wavy-edged film can result from storing 50-percent-equilibrium film at 80-percent RH.

Figure 13

Low temperatures are acceptable if the unopened film has a chance to warm sufficiently to avoid moisture condensation before being opened. High temperatures increase the fading of dye images, film shrinkage, and physical distortions. Other forms of protection for motion-picture film include several printing methods that are used in protecting motion pictures.

Printing Methods for Protection

An examination of motion-picture printing methods raises a number of questions relating to the reasons for certain steps, the choice of materials, and the preference of one method over another. Obtaining the answers requires a thorough knowledge of the films and their chemical processes as well as information about equipment availability, job specifications, and the quality of the end result with respect to the costs involved. If you make motion pictures for a living, you will need to know all of these details before beginning production (or have someone on the staff who can answer the questions). It's important to know what the choices are and why you may choose one particular method over another one.

Here are your printing method choices:

Method A: Let's begin with extended *life expectancy* records—those film documents that need to last for a very long time. Nothing can last forever, but hundreds of years or longer is possible. Color originals should be made on high-quality camera-color-negative film such as EASTMAN EXR Color Negative Film, having a set of properly exposed and processed black-and-white separation positives made for the red, green, and blue records onto EASTMAN Panchromatic Separation Film on ESTAR Base. Then you should store the original negative and separation positives and the master positive and duplicate negative, that were made from the original negative, at the keeping conditions specified earlier.

If later more prints are wanted, and if none of the color material is usable because of fading, shrinkage, or other reasons, the separations can be recombined onto EASTMAN EXR Color Intermediate Film, from which release prints are made.

Method B: If black-and-white separations cannot be made, and you want to keep the films for 10 to 30 years, store the master positive, duplicate negative, and original at conditions specified earlier. For extra protection against shrinkage, the master positive and/or duplicate negative should be on ESTAR Base.

Method C: This method assumes that only prints were made from an original color negative, with no protection masters or duplicates, and that you want to keep the films for about 30 years. Store the negative at 2°C (36°F) with relative humidity at 20 to 30 percent. If the original is a black-and-white negative, the recommended storage conditions would be 25°C (77°F) with relative humidity at 20 to 30 percent.

Method D: These final comments discuss release prints, the commodity used for the show. The colder the storage the better for keeping all films including prints. You can use the figures on page 24 as a guide, but be aware that color prints never were intended to be kept beyond their useful theatrical life, which could be quite short because of possible physical damage to the film. At a room temperature of 24°C (75°F) or colder, with the relative humidity no higher than 60 percent, and if the print was properly processed, the dyes should remain relatively stable for about 20 years. (This dye-stability estimate is based on EASTMAN Color Print Film, manufactured in 1990.)

Important: The optical-negative sound track must also be stored with the same condition as the pictures. Optical-negative sound tracks are always black-and-white silver gelatin. In all of the above methods, cold temperatures will extend the life expectancy.

What to Store if There Is a Choice (In Order of Preference)

1. Your first choice of storage priority should be polyester-base black-and-white separations made from the camera original, including proper contrast ratios. Because these are silver images, they will not fade but could shrink, depending on the storage conditions and the length of time they are stored.
2. Your next choice of storage should be the camera original, master positive, duplicate negative, or internegative. If you follow the specified storage conditions, these materials should be usable for at least 40 years. Some dyes may fade slightly.
3. Your last choice perhaps should be the color print prepared for projection. This material never was intended as a material to preserve a color image beyond its useful theatrical life, maybe that of a few years, depending on abuse. The dyes will maintain a much longer useful life, but physical artifacts, if the print is mishandled, will degrade overall quality.

Classification of Films for Storage

You must consider many factors when deciding on film storage, such as the various combinations among medium and extended life-expectancy storage periods. You need to think about your personal needs; for example, how long will the film mean anything to those who may see it? If it fails as a current document, what about its historical value? A film on how to start a Model T Ford by cranking (**Figure 14**) doesn't have much relevance as current

Figure 14

instruction, but it's a powerful reminder of the route we have come in this century.

When you consider the need for film storage of any kind, you must classify the film for its potential future use by its value as a record and by the length of time that it should be stored. Then find the best answer within your own resources.

For most of you, longer-range storage and preservation will probably not be an issue. You will probably use today's films today, and keep yesterday's films around only between frequent or fairly frequent screenings. You will have to make decisions.

Here is a checklist (**Figure 15**) you can use as a guide:

The storage need is
- ☐ medium term—up to 10 years
- ☐ extended life expectancy—100 years or more
- ☐ combination of these

The films to be stored are
- ☐ acetate or ESTAR Base
  - ☐ black-and-white (silver)
  - ☐ color (dye)
- ☐ nitrate
  - ☐ black-and-white (silver)
  - ☐ color (dye)

The film is
- ☐ camera original
- ☐ release print
- ☐ intermediate form

Figure 15

Actually, only safety film (triacetate or polyester base), which carries silver images, can be used for extended life-expectancy records—500 years for polyester base and 100 years for acetate. In some cases, there may be a combination of nitrate and acetate base films, with either silver or dye images, that have great historical value. You may need to preserve these different films even though you can't afford the expense to go through the separation method. The first thing that *must* be done is to segregate acetate and nitrate films for storage, because the two film bases do not mix, and nitrate is not suitable for any permanent storage record. Acetate-base films can be chemically attacked by the gases given off by the decomposing, unstable nitrate-base films. There is no need to segregate black-and-white and color films that have the same type of base.

We've discussed some of the hazards and problems of maintaining these products over short- and long-term periods under various conditions. Film is very much a match for paper, probably the oldest vehicle used for records and expressive arts. Modern safety film is more resistant to fire than paper. Let's now explore storage factors other than just temperature and relative humidity.

Commercial Storage of Acetate Film

Preparation for Storage

Before you store any films, be sure to repair and clean them. Mount negatives on suitable waterproof cores and prints on cores or reels. Put the rolls inside clean cans, preferably one roll to a can. (With black-and-white separation films, it is advantageous to store all three separations in the same can so they have identical storage histories.) Do not tape (seal) the cans.

Note: Films destined for projection should be wound *emulsion-in,* as specified in SMPTE Recommended Practice RP-39.

Educational-film users (very often do-it-yourselfers) need to carefully consider special situations. Generally, most of us are concerned with only short-term storage of films that travel a lot and often through somewhat less-than-careful hands. Many films are destroyed because they're improperly handled. Your films can lose their educational value before being faced with the question of how to keep them around longer. Nevertheless, it's important to keep them clean and in good condition.

Storage facilities can be fairly simple rooms or closets maintained at about 24°C (75°F) or lower. If the room temperature is regularly at about 75°F, you will need air-conditioning to cool the room and a humidifier or dehumidifier to control the relative humidity at a range of 20 to 60 percent. It's best to have the RH between 20 and 30 percent so you can humidify or dehumidify accordingly. Lower temperatures are always preferable, so be sure to allow enough warm-up time when moving unprotected film to a warmer environment. Keep films out of direct sunlight, even if they are in cans. Sun-struck cans can get very hot inside, even when the room temperature is normal. Vertical storage of film cans (for short-term storage of films that are shipped a lot) allows more air circulation and easy access. For longer storage periods, you should utilize horizontal storage to reduce potential film-distortion problems.

Safe film storage is no better than the reels and containers that are used. Containers must be clean inside and out, and the reels must be in good condition. Bent, chipped, nicked, scratched, or broken reels almost always damage film. To avoid confusion and prevent unnecessary handling, clearly and prominently label the films. Ship films in adequate containers. The purpose of any container is to protect the goods inside, so take extra care to package film for shipping and storing.

Below is a partial list of providers of adequate film containers, or you can contact one of the Kodak offices listed on page 80 for names of other suppliers. These companies are mentioned for the convenience of our customers. This does not constitute a recommendation or endorsement by Eastman Kodak Company.

Motion Picture Enterprises Inc.
P.O. Box 276
Tarrytown, NY 10591
(212) 245-0969

Tayloreel Corporation
155 Murray Street
Rochester, NY 14606
(716) 328-1262

Research Technology International
4700 Chase Avenue
Lincolnwood, IL 60646
(708) 677-3000

Storage Room

Motion-picture film on safety base can be stored safely in any suitable room for a reasonable period. The film, itself, doesn't constitute any more of a fire hazard than an open stack of bound books. So, sprinklers may not be necessary unless required by law.

If the acetate safety film doesn't enjoy the comforts of air conditioning, store it on one of the main floors of the building. Basements are too damp and top floors can be too hot in certain seasons. Get a room away from southern exposures. Use a room protected from accidental water damage from rain, water pipes, sewers, or floods.

Once you locate the ideal storage room, get suitable shelves or steel cabinets. Keep the lowest shelf at least six inches above the floor just in case of water, and keep the shelves and cabinets away from steam pipes, radiators, hot-air ducts, and other heat-producing sources. For long-term storage, stack the films horizontally, rather than on edge, to minimize physical distortion. But don't stack them more than six or eight cans high—because they're heavy and the bottom ones will be difficult to remove.

For film storage, the main thing is to stay away from attics and basements, and to maintain a room that offers a clean, cool, stable environment. Ideally, storage should be separated from work and traffic areas, especially if the collection has a large number (5,000 or more) of prints.

Minimal equipment includes a thermometer and humidity meter. Bare floors are best, no carpets. If possible, install tile floors because tile is easy to clean, and using it lessens the chance of static generation and its attraction of dust to the film. Concrete, if not treated, will create harmful dust. There should never be food, drink, or smoking in the storage area.

Storage Relative Humidity

Processed film is sort of average when it comes to relative humidity. It functions best at moderate temperature and humidity. If there's a significant amount of high relative humidity, monitor the storage room carefully and chart the readings. Prolonged exposure to relative humidity in excess of 60 percent can lead to fungal growth on gelatin emulsions irrespective of the type of film base. Check with the weather bureau to see how long the relative humidity may remain over 60 percent. A dehumidifier may be needed. See the section on "Storage in the Tropics" for the precautions necessary in tropical climates.

Those in arid climates need to be sure that their storage areas are not consistently under 15-percent relative humidity or else film will become brittle. A humidifying unit may be needed. Suitable units are available from manufacturers around the world. Be sure that the controlling humidistat is set no higher than about 50 percent to prevent overhumidification.

Camera originals or intermediates in short term that may be used for printing should be stored at the RH of the printing rooms. This room-to-room equilibrium prevents film size change, which helps to keep the registration accurate while printing.

High relative humidity and temperature, over an extended period, can destroy a film. Low temperatures and humidities can help to preserve films, unless the relative humidity has been below 15 percent for an extended period.

Storage Temperature

Films on safety base are sensitive only at temperatures that run significantly above 21°C (70°F). At about 27°C (80°F) for prolonged periods, distortion is likely. However, even 2 or 3 weeks at 32° to 48°C (90° to 100°F) is not a serious problem, unless the humidity also rises above the recommended levels. Low storage temperatures are best, so long as the RH doesn't get above 60 percent, which can lead to fungus. To prevent moisture condensation, let the films warm to room-ambient temperature before opening the cans. These conditions should be suitable for storage times up to 10 years. Color films will keep better at lower temperatures and relative humidities.

Figure 16 summarizes the atmospheric conditions recommended for medium-term storage of processed motion-picture film.

Recommended Medium-Term* Storage Conditions for Processed Motion Picture Film

Film Type	Temperature	Relative Humidity§ (%)
B&W on cellulose ester base	25°C† MAXIMUM (77°F)	20–50
B&W on polyester base	25°C† MAXIMUM (77°F)	20–50
Color on cellulose ester base	10°C‡ (50°F)	20–30
Color on polyester base	10°C‡ (50°F)	20–30

*A minimum of 10 years; as defined in ISO-2803 or ANSI PH1.43-1985, *Practice for storage of processed safety photographic film.*
†Storage at less than 20°C (68°F) is preferable.
‡For normal short-term commercial storage, 21°C (70°F) at 40- to 50-percent RH is adequate.
§RH of 60 percent should not be exceeded for a medium-term environment.

Figure 16

Storage in the Tropics

If 32°C (90°F) at 90-percent RH is typical for many weeks a year, there is little chance of preserving films without rather special or even heroic efforts. Under these conditions, you must protect films from humidity if you plan to use them later.

The following useful methods of preserving acetate safety film are arranged in order of decreasing cost and convenience; the "top of the line" comes first.

Automatic Air Conditioner—Automatic air conditioning can control both temperature and relative humidity. If the building is also needed for some other purpose, such as a printing laboratory, an economical combination can frequently be worked out. This is not a do-it-yourself task. The services of an architect and an air-conditioning engineer are usually required. This is a very costly investment but well worth the expense in preserving unreplaceable films.

Dehumidifier—The next best method is to dehumidify a small room while keeping the temperature below 24°C (75°F). The room must be kept reasonably airtight to reduce the entrance of moist air. To do this, vapor seal the walls by coating them with asphalt paint, aluminum paint or, better yet, paper-laminated aluminum foil. Weatherstrip the doors and windows. Only then should you install an electric dehumidifying unit. To monitor its performance, install a controlling humidistat that will turn off the machine when the relative humidity has been reduced to about 30 percent.

Such a system will not cool the room. Remember, also, that people working in the room, who may be inspecting or repairing film, need fresh air. Don't confuse dehumidifying units with window air conditioners. The latter do take some moisture out of the air due to condensation on the cooling coils, but they don't control relative humidity. If no moisture is removed from the air, cooling results in an increase in relative humidity. (This is why basements are usually damp.) If the climate is humid, a dehumidifier is necessary. A local heating and air-conditioning supplier can suggest the proper equipment for these needs.

Desiccation with Silica Gel—Rolls of film can be dried by means of activated silica gel. This must be done every time the films are used and is explained in Appendix D. Hopefully, there will be few places in the world with a need to use this type of procedure. Also, remember that the edges of a roll of film dry first, possibly causing some buckle in 35 mm film, a condition that can cause focus problems. Filmhandlers who live in the tropics will need to pay the price of greater care in all film operations. Fungus is a constant threat, especially if the RH is above 60 percent for long periods of time. Refer to KODAK Publication AE-22, *Prevention and Removal of Fungus on Films and Prints.* Frequent inspecting and cleaning are more important for tropical film-handlers than for handlers that live in temperate climates.

Chemical Contamination

Many chemicals surround us, whatever the climate or setting, and constitute a serious threat to safe film storage. Chemical fumes, such as hydrogen sulfide, hydrogen peroxide, and sulfur dioxide (often present in coal-burning regions), may cause slow deterioration of film base and gelatin and gradual fading of color-photographic images. If these or similar fumes are known to be present in your locality, you need to construct a storage facility to guard against them.

One of the reasons why we emphasize the sorting of film types and segregating nitrate-base films from any safety films, is that decomposing nitrate films give off nitrogen-dioxide fumes which damage all three components of acetate- and polyester-base films—the developed image, the gelatin, and the base.

Water Damage

Another hazard for film that can significantly shorten its life is water—from floods, fire fighting, burst pipes, leaky roofs, or other such sources. (And yet, if it wasn't for water, the film could not have been processed.) You can keep water damage to a minimum through quick-salvage actions. Since very few motion-picture laboratories offer film-cleaning services for water- (and mud-) damaged film, a salvage job is usually a do-it-yourself project as mentioned in the following steps and requires manual skill, patience, and a lot of improvising.

1. Keep the roll of film wet. If the film dries, the convolutions may be stuck together, ruining the film. For holding wet or muddy films prior to the cleaning operation, immerse the roll completely in containers of cold water, below 18°C (65°F). The cold water will help prevent both swelling and softening of the emulsion, which are the major causes of damage.
2. With the roll completely submerged underwater, gently rub the edges of the film to remove most of the mud and silt. Make frequent water changes.
3. Unwind the wet film carefully and slowly. Pass the strand of film under running water to remove any remaining mud or silt. In extreme cases, a gentle scrubbing action with a cotton swab may be needed to remove stubborn particles. Be careful in swabbing the film because the wet emulsion is very susceptible to physical damage. From the running water, pass the film through a tank containing water and a laundry or dishwater type of water-softening solution to minimize spotting. Avoid any sudden temperature changes in the wash waters.

4. Drape the film carefully on a wash line to air-dry. Try to keep the drying area dust-free and avoid any surface contact to the wet emulsion side of the film. When the film is dry, clean and lubricate it by hand with a suitable film cleaner (please see warning*), as you wind it onto a reel. The ideal way to recondition water-damaged film would be to have it go through a normal motion-picture-processing machine while using the proper solutions for the particular damaged films. One of the companies that restores or rejuvenates films may be able to help you (see pages 70 and 71).

Inspection

Nothing in the nature of human society stands still. You can't either when it comes to keeping an eye on films in storage, because they are always and inevitably in the process of changing, but sometimes not too obviously or rapidly. You can be sure of their condition only if the films are kept under surveillance. A regular program of inspection is a must!

Remove each roll of safety film from its container and examine it carefully on the outside and at the film end. Please remember to note if there is a vinegar-like (acetic-acid) odor. If there is anything to suspect at all, you should rewind the film and thoroughly examine it. Early detection can save greater effort later and, perhaps, save the existence of a film. Frequency of inspection depends on the quality of the storage and the value of the films.

*The chemicals in this solution may be restricted and in some areas considered toxic.

Figure 17

Where you stay within the safe limits of temperature and relative humidity, an inspection (**Figure 17**) about every 2 years is probably sufficient. But when the climate goes beyond specified limits, increase the inspection program.

If it is truly impossible to maintain this kind of frequent and thorough inspection, you should at least sample the stored films to detect early problems that may be affecting other films. Do not fall into the comforting habit of looking only at the same films or inspecting within the same areas of the storage room. And please, if there is any sign of fungus or vinegar-like odor, or other film damage, widen the search immediately, so that corrective action can be taken. Often the first indication of deterioration of acetate films is the very distinctive previously noted vinegar-like (acidic-acid) odor when the film container is first opened. If the situation is bad, you may need help. Be sure only those people who are familiar with good film-handling techniques are involved with inspection and segregation.

Extended Storage of Processed Acetate Film

No existing film archive has yet been put to the test of preserving vital film documents for centuries, as libraries have with their paper documents. The best information from which we can project that kind of success is gathered from accelerated testing procedures. It attempts to predict the fate of photographic materials up to a century or more. It does so by using our knowledge that heat seems to speed up history, so to speak, by accelerating the natural chemical processes that affect film.

The film archivist is responsible for materials that have great historical or aesthetic value. Since film is barely a century old and has gone through continuous research and development, you are not dealing with a set of settled questions and answers. What holds for one film may be less true, or not true, for another. You must know what kinds of films you have and what

characteristics of their long-range life are known. Actually, you can use only black-and-white (silver) images on safety or polyester base for strictly extended life-expectancy purposes (see earlier section).

One of the best ways of providing maximum protection for the longest keeping times for film, or any other medium, is to store one or more copies in different locations. No matter what precautions you take, there is always the chance of an accident. With motion-picture films, storing the original, separations, master positive, duplicate negative, internegative, or print in different locations makes a great deal of sense. Storing them at different locations doesn't mean within the same building but many miles apart to protect them against fires or major natural disasters. Let's look at ways of providing the best possible protection before discussing reasonable compromises.

Specifications for Extended Storage

Follow these procedures for extended film storage:

1. Use safety film stock that meets the requirements of ANSI IT9.11, *Imaging Media—Processed Safety Photographic Film—Storage.* The scope of IT9.11 is detailed earlier in this chapter. Polyester base is preferred.
2. Store the film on a moisture-proof core in a suitable corrosion-resistant can stacked horizontally on a shelf. Do not seal the can.
3. Locate and construct the storage space as a 6-hour fire-resistive vault according to state and local building codes; the Fire Underwriters' regulations (U.S.A) permit an approved air-conditioning installation (more on this later).
4. Protect the film from water damage of any type.
5. Provide sufficient insulation with a suitable vapor seal to permit satisfactory temperature control during all seasons of the year and to prevent moisture condensation on, or within, the walls.
6. Condition and control the air automatically at 20- to 30-percent RH and not over 21°C (70°F), (see **Figure 16**). Take necessary precautions to prevent moisture condensation on film after removing it from the vault. For color films, colder storage temperatures are strongly recommended and additional recommendations may be available from the film manufacturer or from ANSI.

Preparation for Storage

If there is any doubt that the fixing and washing of the film were adequate to meet ISO or ANSI Standards, analyze it for residual hypo (see **Figure 10**). If there is more hypo than the standard calls for, have the film properly rewashed but only after it's confirmed that the gelatin in the emulsion hasn't already been damaged by fungus or moisture and become water soluble. If this has happened, clean the film as described in Chapter 5, and duplicate the film on fresh stock.

Do not expend energy on valuable film that is not clean and repaired. When you're ready to store the film, wind it on a suitable rustproof core and place it in the best metal can available, replacing the old can with a new one as needed. Be sure that the lid is loose fitting to let in conditioned air while keeping out dust. If you must use film in an area where the relative humidity is below 15 percent or above 60 percent, allow it to be reconditioned to the storage area's relative humidity before returning it to the can.

Storage Vault

The archival storage vault for acetate or polyester film doesn't need to be as impressive as King Tut's tomb. However, it must be protected from outside fire, even though the safety film itself (nitrate is not a safety film) isn't a fire hazard. Fireproof buildings sometimes make us complacent, so we forget that furnishings, wiring, and other contents may be hazards.

If your vault is constructed to withstand 6 hours of severe fire exposure, it is probably safe enough. Shorter-duration protection will be less expensive; you have to decide what you can afford. Also get help from an architect or engineering firm for the requirements necessary for constructing valuable record vaults, eg., location, building materials, wall thickness, type of door, etc. Such information is published by the National Fire Protection Association, One Batterymarch Park, Box 9101, Quincy, MA 02269. Telephone (617) 770-3000.

The vault should be located on either the ground floor or upper floors in a fireproof building, provided that the supporting and overhead floors are of sufficient strength. A basement is often damp and sometimes can become flooded.

Figure 18 shows a design, illustrative only, of a 6-hour fire-resistive vault. Its convenient dimensions are 8 feet wide, 10 feet high, and 15 to 20 feet long. Standard steel shelves along both side walls provide horizontal stacking of film cans. The shelves should be approximately 12 inches wide for 1,000-foot rolls and 18 inches wide for 2,000-foot rolls. Remember that films can stand on edge for ordinary short term *in-use* storage but should be placed horizontally for long-term storage. So calculate your long-range needs carefully before you decide on vault dimensions for horizontal stacking.

The National Fire Protection Association advises against air conditioning in valuable (paper) record rooms because of possible fire hazard from the outside coming through the duct work. If the climate is a problem, there probably is no choice. Proper air conditioning is almost always essential for long-term preservation of extended life-expectancy storage of films. The fire hazard introduced by the openings in the room for air-conditioning ducts may be overcome by the use of Underwriters' approved automatic fire-control dampers in ducts, installed in accordance with recommendations of the National Fire Protection Association.

An automatic sprinkler system inside a fire-resistive vault containing only safety films is not necessary. Its elimination decreases the danger of accidental water damage to the films. If a sprinkler system is not installed, keep out all combustible furnishings and materials other that the safety films and the metal containers. In this connection, consult local building codes plus the Fire Underwriters' and National Fire Protection Association's regulations concerning valuable record rooms. If you use automatic carbon-dioxide fire-extinguishing equipment in the film vault, you **must** have a warning device to permit anyone in the room to escape before the carbon dioxide is released.

Air Conditioning

Choose a competent air-conditioning engineer; then work closely with that expert to be certain that the equipment recommended is capable of maintaining the temperature and humidity conditions needed year-round. To help you deal with the air-conditioning engineer, here are some important concerns. The local climate is an important factor. Sufficient fresh air is necessary to keep the room under a slight positive pressure for ventilation and to prevent the entrance of untreated air. A spray-chamber-type of air conditioner is probably indicated.

To avoid breakdowns and costly repairs, be sure to consider equipment constructed of corrosion-resistant, high-quality materials. Ideally, the conditioner should be located outside the vault for ease of maintenance and to prevent leakage of water in the vault in case of a breakdown. The conditioner housing and all duct work should be well insulated. The control of room conditions calls for appropriate instruments, such as a dry- or wet-bulb thermostat, hydrostat, or dew-point controller.

Economizing to some extent (never recommended) may be done because of the leeway in temperature relative-humidity requirements for the life expectancy of the films. It is possible to pass air through a cooling coil to freeze out excess moisture and then reheat the air instead of using a spray chamber. This technique prevents high humidity—the greatest danger to film—but doesn't prevent low humidity in dry seasons. Although this doesn't meet the requirements of the ANSI or ISO Standards, it allows the use of a lower-capacity cooling system. You should check temperature and relative humidity daily with the proper equipment or use a continuous automatic-monitoring system.

Clean the vault frequently to prevent the accumulation of lint from clothing and dirt from shoes, etc. If a spray chamber is used in the air conditioner, and the water is recirculated, clean the chamber too. This will prevent the formation of biological slime that can eventually decompose and give off hydrogen sulfide, one of film's chemical enemies. Air-purification units also require occasional servicing. Take safeguards when equipment is turned off for maintenance or out of order.

Air Purification

Filter all air supplied to the room to remove dust. The removal of sulfur dioxide, hydrogen peroxide, hydrogen sulfide, and other such gases requires special consideration; they're often found in harmful concentrations in the atmosphere of urban and industrial areas. Determine how much these gases are a factor to the vaults. This question is somewhat complicated by the fact that safe standards for these gases in connection with film storage have not been determined. No actual safe limit of sulfur-dioxide concentration for extended life-expectancy storage of film can be suggested, but it suffices to say that even a low concentration, along with other ambient air contaminants, may be harmful to film stored over a long period of time.

If there is atmospheric contamination in your locality, consult an environmental engineer to help you select the best type of air scrubber, activated charcoal absorber, or other air-purification equipment for the situation. You may benefit from an installation like that at the Harvard Rare Book Library with its Gutenberg Bible and other treasures.

Inspection

You don't need to inspect films stored under the conditions specified for extended life-expectancy storage as frequently as those stored under uncontrolled or adverse conditions of commercial storage. But you should still inspect films in extended storage at least every 2 years.

Special Considerations for Color Films on Safety Base

All films require special preparation for long-term storage, with added attention to color, because of the three dye layers. The dyes used in EASTMAN Color Films are as stable as is consistent with the optical and chemical restrictions placed upon them by the nature of the color processes. Nevertheless, all dyes fade somewhat in time. Many valuable color films exist and need to be preserved as long as possible.

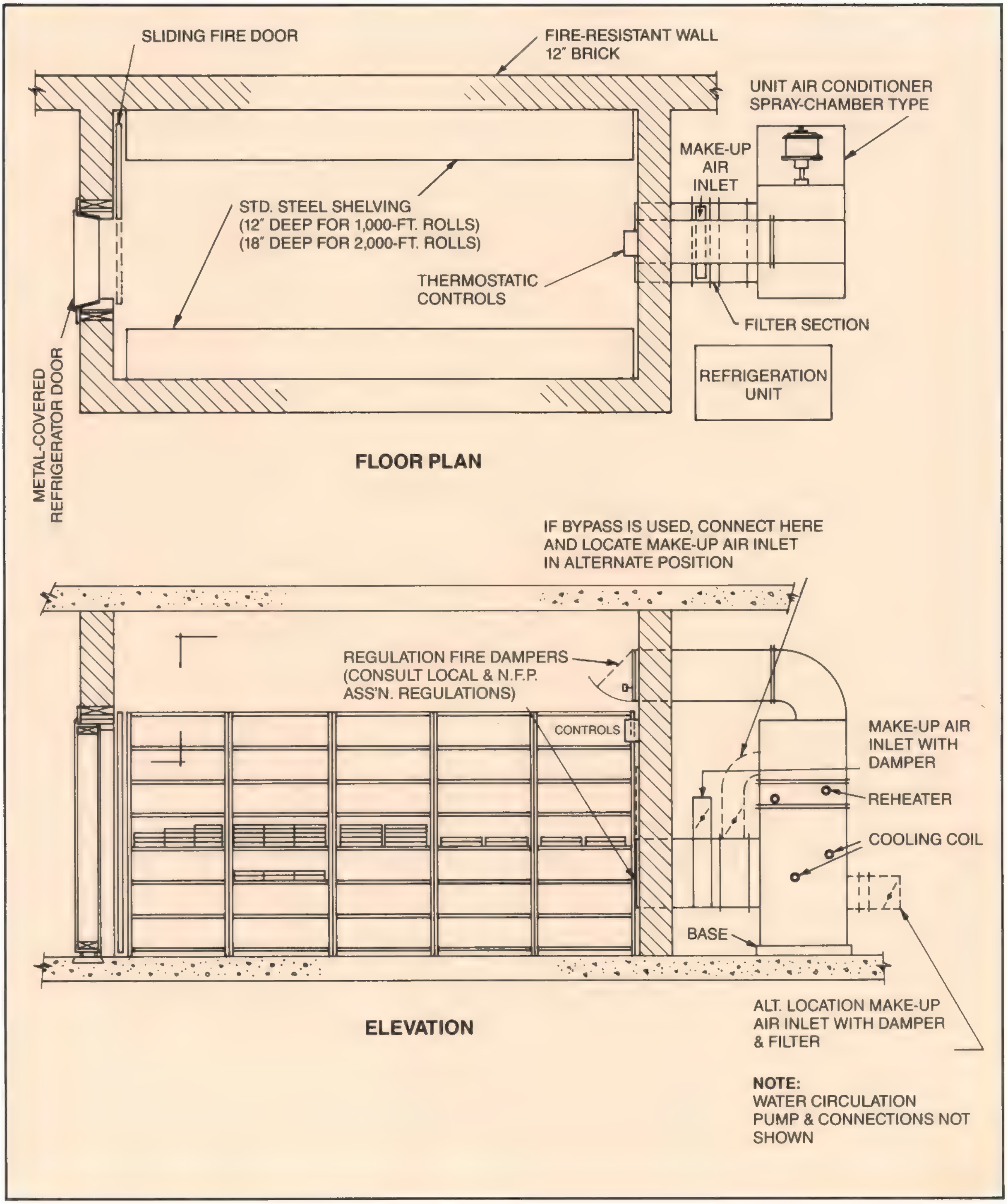

SLIDING FIRE DOOR
FIRE-RESISTANT WALL
12" BRICK
UNIT AIR CONDITIONER
SPRAY-CHAMBER TYPE
MAKE-UP
AIR
INLET
STD. STEEL SHELVING
(12" DEEP FOR 1,000-FT. ROLLS)
(18" DEEP FOR 2,000-FT. ROLLS)
THERMOSTATIC
CONTROLS
FILTER SECTION
REFRIGERATION
UNIT
METAL-COVERED
REFRIGERATOR DOOR
FLOOR PLAN
IF BYPASS IS USED, CONNECT HERE
AND LOCATE MAKE-UP AIR INLET
IN ALTERNATE POSITION
REGULATION FIRE DAMPERS
(CONSULT LOCAL & N.F.P.
ASS'N. REGULATIONS)
CONTROLS
MAKE-UP AIR
INLET WITH
DAMPER
REHEATER
COOLING COIL
BASE
ELEVATION
ALT. LOCATION MAKE-UP
AIR INLET WITH DAMPER
& FILTER
NOTE:
WATER CIRCULATION
PUMP & CONNECTIONS NOT
SHOWN

Figure 18

One possibility is to make panchromatic black-and-white copies of valuable color films onto polyester-base films for extended life preservation. This is sometimes done, but one could feel that it violates the first principles of the archivist, namely, to preserve the record in its original form, which in this case means color. Another possibility is to make three black-and-white separation negatives from the color print. You could use them to make a new color print through a color intermediate system at any future time. This is an expensive procedure but probably justified. A similar procedure (making a separation master from a color negative) was discussed earlier, see "Classification of Films for Storage" on page 22.

Factors that contribute to fading of color films are heat, moisture, and light. Projection of motion-picture film is so rapid and the form of storage is such that light is not much of a problem. For optimum preservation of the dyes in color film, store the film in a cold, dry environment for maximum permanence. The storage temperature should be 2°C (36°F) or lower with relative humidity at about 20 to 30 percent.

Laboratory tests show that the dyes in color films keep even better if the RH is lower than 20 percent. However, the lower the moisture content of the film, the more problems you'll encounter from brittleness, curl, spokiness, and other film distortions. From a strictly physical standpoint, a relative humidity of 20 to 30 percent is considered best. It's important to arrive at a reasonable compromise for your purposes and conditions.

Conditioning Film

Ideally, the film should be put through some sort of conditioning cabinet with air circulating at about 30-percent RH. The key word here is ideally; none of our consultants can suggest where we might acquire such a cabinet. An alternative, one that could work very well, is simply to dehumidify a small, relatively airtight room and precondition the film there. Readily available commercial dehumidifiers, such as those designed for damp basement use, should be adequate in most cases. Expose the film (single strand) to such conditioned air long enough to bring the film nine-tenths of the way to equilibrium (70- to 20-percent RH, for example). In some instances, particularly in areas of very high humidity, you may have to condition the air somewhat to maintain a 30-percent RH in the room (consult a psychometric chart).

Accurate control of the moisture content of films requires some analytical facilities and technical supervision. Never desiccate any collection of color films of appreciable size and value, to be preserved indefinitely, without such facilities.

Electronic Storage

While it's possible to transfer a film image electronically to storage mediums, such as video disks and tape for future retrieval, it's not recommended. Just as film has only about 100 years of *storage* history, electronic storage has much less. Another reason for non-electronic storage is equipment. Will a particular piece of equipment be available 100 years from now when the material needs to be retrieved? Will the storage system be compatible with *newer* state-of-the-art storage and retrieval methods? We urge caution on the use of anything but film on polyester support for extended life expectancy of film products. Film remains about the only product that has consistency worldwide for mechanical specifications.

Storage and Handling of Processed Nitrate Film

Nitrate-Base Film

Nitrate base, the pioneer of motion-picture film bases, retired from our cameras and laboratories about 1949. Still, its very long shadow of distinguished commercial motion pictures and film records haunts many film vaults. Nitrate-base films must be handled with informed care.

Cellulose-nitrate-base film is relatively unstable. If you store it in large quantities of about 5,000 feet or more and in non-approved storage cabinets without proper ventilation, it becomes a fire hazard. Admittedly, it takes a bit of pushing to cause it to burst into flames spontaneously. For example, in one laboratory test, combustion occurred with a decomposing 1,000-foot roll of film only after it was kept at 41°C (106°F) for 17 days tightly encased in a can wrapped in insulation to retain the heat of decomposition. However, even a minor fire can cause major film losses. This example may not be that different from some storage lofts in the summertime that are uninsulated.

Cellulose-nitrate decomposition is the villain (**Figure 19**). It shrinks, even to the point of becoming unusable. Furthermore, as the film breaks down, it gives off nitric oxide, nitrogen dioxide, and other gases that yellow the film base, yellow and soften gelatin, and oxidize the silver image. Later, the base cockles, becoming very brittle and then sticky. Finally, it disintegrates completely. This inevitable deterioration is usually gradual, but elevated temperatures and humidity speed it greatly.

Figure 19

While it deteriorates, nitrate-base film makes a kind of pressure cooker of the film can in which it rests, especially when it's taped closed. If the gases can't escape, heat builds and spontaneous combustion may not be far behind. Therefore, nitrate film **must never** be closed in.

Escaping toxic gases (powerful oxidizing agents) can attack nearby acetate- and polyester-base films, so store nitrate films in their own special place and not in a place too heavily concentrated.

If the conditions are right, their image layers may last for decades or generations. Because of their great value, many nitrate-base films have been reprinted on current longer-lasting safety base. Somewhere, nitrate film is still with us, so we offer a few more comments.

Probability of Rapid Decomposition

If you store old nitrate-base films, the first thing you need to check is the temperature of the storage area. High readings of the temperature and/or the relative humidity are unfavorable to nitrate and to other films. Are the by-products of decomposition being discharged from the storage area? Is there too much nitrate in a confined area? The more rolls collected in one place, the greater the chance of trouble. With nitrate film, it's important to design separate and specialized storage compartments.

Inspection and Segregation of Nitrate-Base Film

Identification is the key to initiating the proper handling of nitrate film. You need to properly identify the films in your vaults and storage areas. Don't assume all films to be acetate or polyester when some may be nitrate. Some rolls may be spliced mixtures of each. Kodak never produced 16 mm or narrower film on nitrate base. Some may have been slit to 16 mm from 35 mm for whatever reason. Also, Kodak never produced 70 mm or 35 mm color camera original or color print films on nitrate base, but they did produce on nitrate base a special black-and-white Eastman nitrate film for use in making 35 mm and 70 mm imbibition films (dyed by the Technicolor process).

It's important to know exactly what types of film are in your possession because nitrate fumes and fire are a threat. Conditions that may only marginally harm the acetate films can cause a nitrate base to become very dangerous. Unless you can detect some deterioration, you may have a hard time differentiating nitrate- from acetate-base films. Edge identification (**Figure 20**) may establish the difference the easy way.

You can use ultraviolet lamps to identify EASTMAN Triacetate Films by the resulting fluorescence (**Figure 21**). A different identification tool is your nose. Cellulose nitrate has a characteristic acid odor, similar to that of nitric acid. This odor is unmistakable when a quantity of nitrate film has been stored, especially in a non-ventilated area. Appendix B—Laboratory Tests for Identifying Acetate- and Nitrate-Base Films, gives complete information on a simple burning test that will determine which of the films is nitrate.

Note: A test for determining if the film is acetate or nitrate is given on page 73.

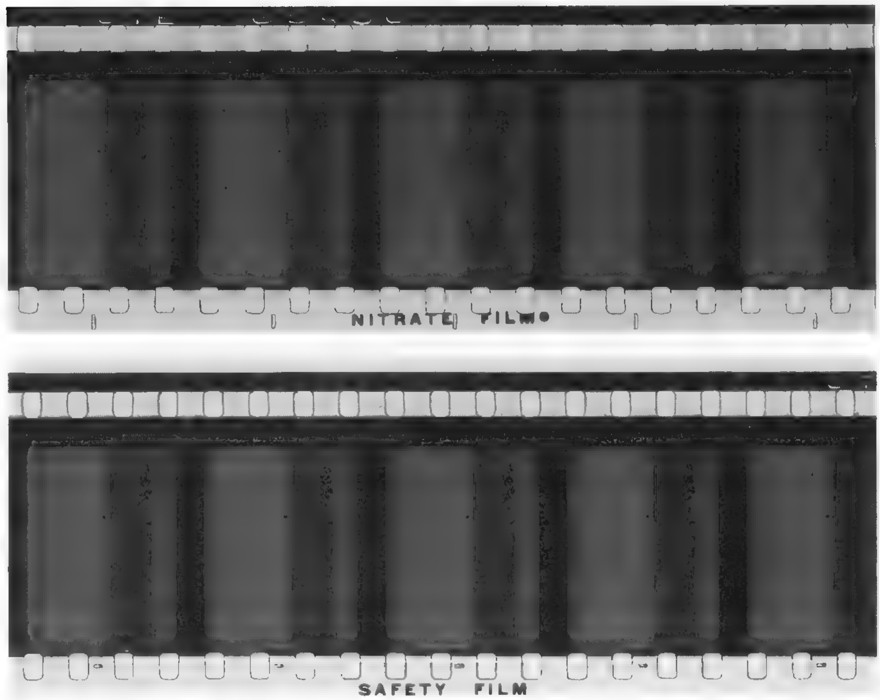


Figure 20

Figure 21

Evaluating the Extent of Deterioration

The nitrate film you have in storage may be middle-aged, but if it was properly stored, it may be quite usable. However, if it was neglected, it may be showing signs of early deterioration. One way to determine the extent of deterioration is to look at the color of the base. If it's yellowish, or even amber, sulfiding has begun because of silver in the emulsion and some yellowing of the gelatin. The confirming test is to see if the film base is brittle and breaks easily on being bent in half, especially with the emulsion side out. At this stage, the gelatin is probably soft enough to dissolve readily if the film is wetted.

If these symptoms of decomposition are found, handle the film with care and keep it dry. Duplicate it soon after inspection, drying, and cleaning, because buckled film and sticky gelatin may make duplication later more difficult or perhaps impossible.

Spontaneous Combustion

Spontaneous combustion is self-ignition of combustible material through chemical action (as oxidation) of its constituents. It develops from knowable conditions, such as deterioration, and with proper observation and care, you can prevent a chemical reaction. Non-preventive measures, whether it's in hay, oily rags, or nitrate film, can result in a fire. With the information given in this section, you can prevent the threat of spontaneous combustion.

Apparently, fire isn't caused by cellulose nitrate in *good* condition. But in the advanced stages of decomposition, self-ignition takes place at sustained temperatures only slightly above 38°C (100°F). If undetected, heat-producing deterioration and high temperatures, with consequent heat buildup, coincide. Such combustion isn't nearly so *spontaneous* as its name seems to imply!

Storage Vaults and Conditions

Carefully examine all the materials known to be on nitrate base. Detecting unstable nitrate film is by far the most important way to preserve this material. If decomposition isn't found quickly, complete destruction of the film record may result. Spot inspection only needs to be done once a year if you follow the recommended storage conditions, and once every 3 months if adverse conditions exist. Any nitrate film that is badly buckled or sticky (**Figure 22**) is in an advanced stage of decomposition.

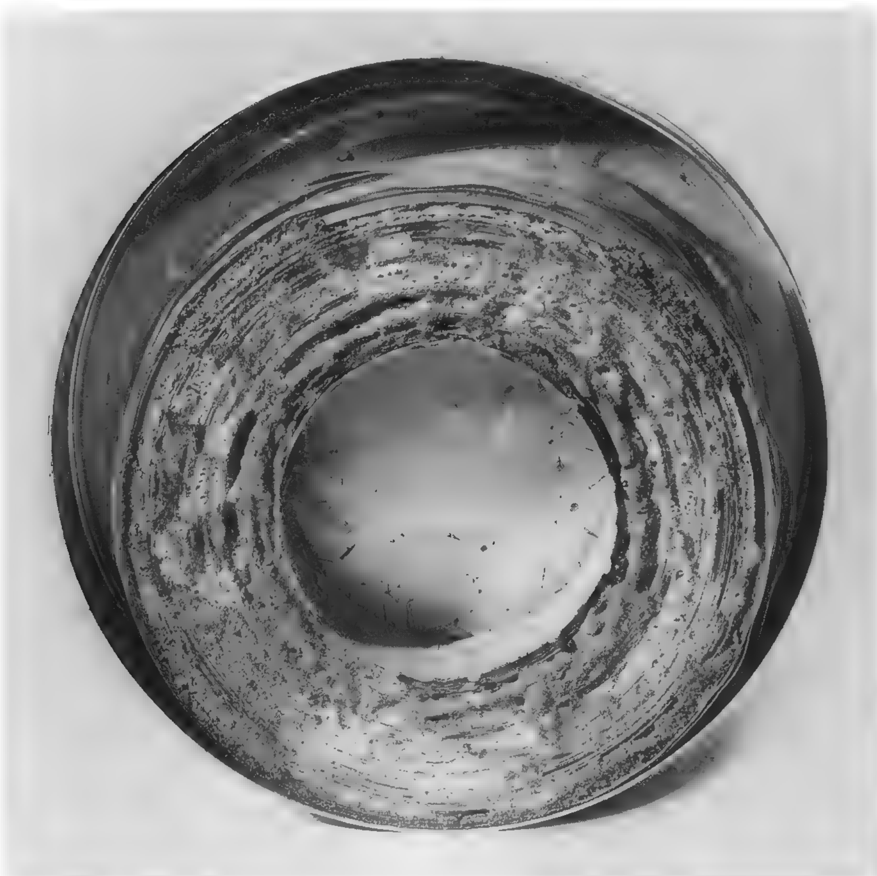


Figure 22

You may be able to duplicate some of these badly buckled or deteriorated films, or they may yield a fair-quality print. Urgency is the word. If the film base is heavily stained and moisture from our breath makes the gelatin slightly sticky, the negatives or prints must be duplicated within 2 years while maintaining proper storage conditions.

Never wet a decomposing nitrate-base negative; the gelatin may be readily dissolved. If you must remove surface dirt, use a quality cleaner carefully. Many old negatives have an iridescent dichroic or silver-sulfide stain, usually on the surface of the gelatin. This is a further sign of old and deteriorated film.

Store these negatives only in small quantities and in different locations. The production of chemical vapors and heat from large concentrations of nitrate films demands special storage conditions with a special exhaust and ventilation system. This storage area should never be near safety films.

Never store any nitrate-base materials in sealed containers or without ventilation. Such dead storage simply increases the rate of decomposition. Pack the reels loosely in ventilated metal boxes or cabinets, and store them in a room apart from all other photographic materials. Do not let the storage area temperature exceed 21°C (70°F). If you achieve a lower temperature without increasing relative humidity above 45 percent, that's even better. Relative humidity below 40 percent retards decomposition even more, but makes the film more brittle.

For longer storage, use an approved storage vault. The standards for design, construction, and use of storage cabinets and vaults for historical nitrate films are based on years of experience by the National Board of Fire Underwriters and are supported by the experience of the National Archives and the National Bureau of Standards.

The important principles supporting the Underwriters' regulations are based on–

- elimination of all possible means of starting a fire
- control of, and protection against, the spread of fire
- segregation of large quantities of film into small protected units
- ample provision for safety to human life
- proper ventilation and exhaust system

These are the important reasons behind every detail of an approved building construction, self-closing fire doors, exits, vents, light fixtures, electrical systems, heating equipment, and automatic sprinklers, etc.

Vaults for *commercial* storage are limited to 750 cubic feet with a vent area not less than 200 square inches per 1,000 pounds, or a total of 2,000 square inches for the standard-size vault. A sprinkler is required for every 62.5 cubic feet of space or 12 for a 750-cubic-foot vault.

Vaults for long-term storage are limited to 100 cubic feet with a vent area of at least 2,670 square inches, and with no less than eight sprinklers. Both sprinklers and ventilation provide about five times the safeguards suggested for that of commercial storage.

Shelves in long-term film vaults should be divided into individual compartments with not less than ⅜-inch thick non-combustible insulating material. Each compartment should hold only one, or at most two, film containers.

The ceiling water sprinklers should be directed so that all shelves will be drenched in the event of fire. The individual containers will protect the film from water damage.

Air-conditioning systems in film vaults should be installed according to regulations of the National Board of Fire Underwriters. Automatic fire dampers should be installed in the air ducts so that a fire in one vault will not spread to another and so that the toxic gases given off will not be distributed to other rooms, but will be vented outside. The Underwriters' regulations do not provide for control of air temperature and relative humidity in the storage of nitrate film other than that temperatures must not exceed 21°C (70°F). This is a safety precaution. Additional precautions are required from the standpoint of film preservation.

Nitrate Storage Conditions

The air conditions recommended for nitrate film storage are listed below. For *temporary-* or *medium-term storage,* temperatures up to 21°C (70°F) at relative humidities between 20 and 50 percent are considered satisfactory. Where this maximum temperature and humidity are exceeded and complete air conditioning is unavailable, dehumidification by machine would be of some advantage. Cooling alone, without automatic relative-humidity control, is also beneficial, since a considerable amount of moisture can be condensed out of the air on cooling coils. Remember that all nitrate films are at least 40 years old. If possible,

Nitrate Film Storage

Film Type	Medium-Term Storage		Long-Term Storage	
	Temperature	Relative Humidity (%)	Temperature	Relative Humidity (%)
B & W	below 21°C (70°F)	20–50	below 10°C (50°F)	20–50
Color	below 21°C (70°F)	20–50	below 0°C (32°F)	20–30

Figure 23

you should store them as recommended (**Figure 23**) for films of long-term historical value, but because of their nature, they should be copied and then destroyed.

Proper nitrate film-storage conditions require some expense to achieve. Lower relative humidities than those recommended would retard decomposition of nitrate film and fading of color images even more, but most experts agree that the risk of brittleness with old nitrate film is too great. Remember that color and nitrate-base films do not qualify for extended *life expectancy*—in the hundreds of years. But proper storage conditions can prolong their useful life. For the American National Standards Institute (ANSI) and National Fire Protection Agency (NFPA) for nitrate-storage recommendations, refer to ANSI/NFPA Standard 40-1988, *Storage and Handling of Cellulose Nitrate Motion Picture Film.*

Caution: Never seal nitrate film in an airtight container at any time. The gases and heat created while in storage must be allowed to escape.

Disposal

After nitrate-base films have been duplicated, they should be destroyed. Never discard nitrate film into ordinary trash containers or into routine disposals. Check with the local environmental agency for safe disposal. Never mix nitrate-base film with safety film that will be sent for silver recovery.

You **must** handle unstable or deteriorated nitrate films much like you would explosives. Keep such films *underwater* in an open suitable steel drum until disposal can be arranged. Regard as unstable any substantial quantity of films, whatever their apparent condition.

The safest and most environmentally sound method of disposal for nitrate films is high-temperature, supervised incineration (but not in roll form, could explode) coupled with effective air-pollution control. If *on-site* facilities are not available, a commercial, environmentally certified waste-disposal firm should be utilized. Open burning of waste nitrate film is dangerous as well as regulated by local, state, and federal environmental laws.

Danger: Nitrate film should never be burned in a heating furnace because the gases generated by the burning produce high pressure (explosive) and are highly toxic!

Help for Owners of Nitrate-Base Film

Nitrate-base films have been out of common use so long (since about 1949) that expertise in handling them is not commonly offered, but there is a listing of facilities that do offer this service (see pages 70 and 71). Unless you are an expert concerning the characteristics of nitrate films in various stages of decomposition, **don't** unroll the films. Let the experts do it.

For help determining the historical (not monetary) value of any material on nitrate base, contact a local historical film association or International Film Archive, FIAF Secretariat, rue Franz Merjay 190, 1180 Brussels, Belgium. If they can't help you, they'll direct you to someone who can. If the film has value or you decide to have it duplicated, even if it isn't unique, one of the film archives can give you advice on the procedures for arranging duplication. Or, you can contact one of the companies listed on pages 70 and 71.

Note: Nitrate-base films can't be mailed, so you will need to arrange some other method of conveying them.

And so we bid a fond farewell to nitrate-base film—a great pioneer resource, still highly valued, but always a challenge to our most careful film-handling and storage techniques.

CHAPTER 4

Dye Stability

Color images in books, magazines, television programs, and motion pictures are so common today that it is difficult to imagine the effect of a world of photographic black and white on those who first experienced it. In those early times, the sheer impact of watching (in amazement) any kind of moving images far outweighed the sense of loss of the missing color.

Nevertheless, for decades, people tinted their motion pictures, sometimes by hand. Even in motion pictures like *Intolerance,* whole sections were tinted for symbolic impact (**Figure 24**). When living color came to the movies, the color at first seemed almost supernaturally vivid. This miracle of *color* depends on only three dyes (cyan, magenta, and yellow) coated in three separate layers on the same film base. For centuries, dyes have been extracted from earth and plants and applied to pottery, fabrics, and whatever else would accept the colors. Dyes and inks color so much of our world that we tend to forget that they don't just happen.

Since most movies include pictures of people, the rendering of flesh tones is vital in designing an effective color film. The reproduction of neutrals (whites, grays, and blacks) and of common *memory* colors, such as blue sky, grass, sand, etc., is also important. As a result of designing film to reproduce these colors well for various exposures and processing conditions, some other colors—such as shades of chartreuse, lime, pink, and orange—may not reproduce as well. It would be possible to design a film to render these colors better, but then some of the more important colors would suffer. Color films don't have exactly the same color sensitivities as the human eye. For most subjects, it's not necessary that the three light-sensitive layers of the film *see* the subject exactly with the same wavelength-sensitivity relationship as the human eye, but simply that the accumulated effects of red, green, and blue light be in the same ratio to the film as they are to the eye. More has been written on this subject, but it's not useful for our present purposes, except to realize that any dye system has limitations.

The responsibility for preserving color motion pictures rests both with photographic manufacturers and with those of you who use these films to make motion pictures worth preserving. The manufacturer searches for new and better dyes, while trying to help users to understand the capabilities and limitations of current color film stocks. Manufacturers and users are only the ends of the long chain of people who are ultimately involved in this quest; for everyone who handles these films as processor, shipper, projectionist, librarian, or archivist, bears part of that responsibility.

The manufacturer looks for the best dye stability that is technically and economically possible, while maintaining other important photographic properties such as color reproduction, sharpness, and processability. The manufacturer's consideration of the best dyes, emulsions, and processes must also operate within compromises necessitated by the toxicity of chemicals, the cost of materials, reactivity and color of dyes, compatibility of dyes with the process, and the cost of the process. This is no simple matter.

The manufacturer provides the best relevant information possible on the stability of these dyes, especially as they are impacted upon by various temperature and relative-humidity levels, and exposure to various intensities and wavelengths of light. Gases, such as formaldehyde, hydrogen sulfide, hydrogen peroxide, sulfur dioxide, ammonia, coal gas, and automobile-engine exhaust, can also affect dye stability. With so many variables, and with so many of them unpredictable, the only reasonable database line is the manufacture for film keeping at varying temperatures and fixed relative humidities.

Predictive Testing

The best measure of color motion-picture dye stability is how the product performs in the customer's hands. The chemical reactions involved in the loss of dye are so complex and so slow (usually), depending on the storage conditions, that accelerated test procedures were devised.

Predictive testing of color materials can be useful in telling how much dye will be lost and how fast by using standardized accelerated keeping conditions. These accelerated tests using high heat and fairly high humidity don't give us as accurate a prediction of real-life conditions as we would like, but they are reasonable predictors.

The accelerated test procedure consists of incubating processed sensitometric strips at several different elevated temperatures—all at the same relative humidity. Density measurements are made at a specified time interval during treatment.

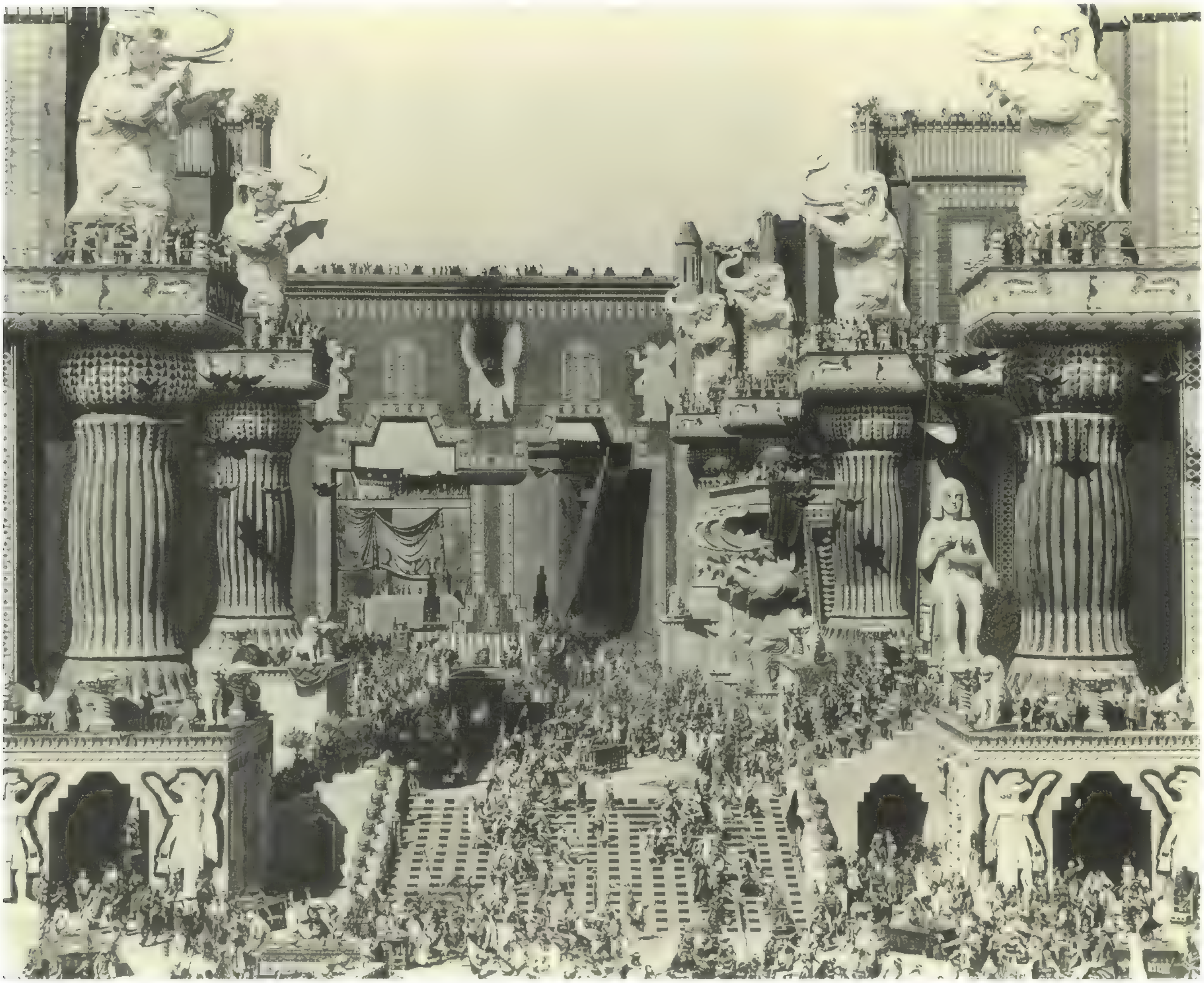


Figure 24

Why Dyes Change

The fading characteristic of a dye image depends on the type of dye or dyes used to produce it, the care with which it is processed and handled, and the conditions of storage. Color films are always being improved, and over the years Kodak has offered improved dark-keeping dye stability motion-picture films.

No color film is ideal in every respect. For that reason, notices have alerted users to the fact that color dyes may change in time. Even ANSI does not publish a specification for motion-picture-film dyes. The film's dye stability is only one of several important factors considered in the research and development leading to new color film products. Other factors are emulsion speed, tonal scale, grain, sharpness, and color reproduction.

Varying requirements result in the use of different dyes, so rates of fading are not the same for all color materials, or even for the different layers in a single film. Dye fading may be photochemical (light fading) or chemical (dark-keeping fading) and its rate is closely related to the way the film is processed and stored.

All color films eventually fade, as do all colorants. However, the total amount of light, radiant energy (intensity X time), used in projecting a motion-picture print, even hundreds of times, is minimal, so light fading is not normally a concern with motion-picture films. Chemical fading will occur even when the film is not in use and is stored in a light-tight container, although dark-keeping fading is the area of greatest concern.

Regardless of how complex the question of dye stability is, the fact remains that if you select the proper film, process it properly, and keep it under recommended storage conditions, the product will be amply protected for generations.

Motion-picture film is a very complex product. Manufacturing is asked to apply three extremely thin layers onto a base to register and even enhance the whole spectrum of color in the sometimes fallible mind's eye. Color negatives are turned into color positives that may be copied, changed in dimension, and always enlarged in projection. And what is projected on a screen may not reflect very well the color registered in the film layers.

Influence of Temperature and Humidity

As with many other chemical reactions, dye fading proceeds at a reduced rate at low temperatures. If you choose as reference points a room temperature of 24°C (75°F) at 40 percent RH, you can examine the relationship of temperature to dye loss in **Figure 25.**

Effect of Temperature on Dye Fading Rate at 40-percent RH

Storage Temperature	Relative Fading Rate*	Relative Storage Time
30°C (86°F)	2	½
24°C (75°F)	1	1
19°C (66°F)	½	2
16°C (60°F)	¼	3½
12°C (54°F)	⅕	5
7°C (45°F)	1/10	10
–10°C (14°F)	1/100	100
–26°C (15°F)	1/1000	1000

*The values given in Figure 25 are approximate and do not apply exactly to all color films or color photography products that contain dyes. The values can, however, be used to help you plan for proper storage conditions for most color film products.

Figure 25

The values given are approximate and don't apply exactly to any particular color film. You can use these values to help plan for proper storage conditions for most color film products. Notice that film stored at temperatures as high as 30°C (86°F) has a relative fading rate twice that of film stored at 24°C (75°F). Also, the advantage of moving from 24°C (75°F) to 7°C (45°F) is that the relative fading rate is only one-tenth as fast. Lowering the temperature further to –26°C (–15°F) improves the relative fading rate 1,000 times compared with the average room temperature at 24°C (75°F).

To further emphasize the extent to which temperature influences dye stability, let's take as an example a film that was stored at a room temperature of 75°F at 40-percent RH for a number of years; you would notice a cyan-to-red color shift. If that same print had been stored at 40°F at 40-percent RH, the same level of fading would not occur for nearly 100 years. Stored at 0°F at 40-percent RH, it would take more than 2,000 years! Keep in mind, these figures are of necessity predicted from accelerated test data, the best predictors available so far. The validity of tests continues by comparing predictions at elevated temperatures with performance at ambient (or lower) temperatures.

Since the preceding are temperature comparisons, you will note that the relative humidity is constant at 40 percent. Humidity also has a substantial effect on dark-keeping dye stability of photographic products, particularly in the yellow dye layer. It is interesting to find that most people seem to be fairly tolerant of losses of yellow dye. Some humidity effects are shown in **Figure 26**.

Effect of Humidity on Dye Fading Rate

Relative Humidity (%)	Fading Rate	Storage Time
60	2	½
40	1	1
15	½	2

Figure 26

If you store the same roll of film in an area that averages 60-percent RH, using the norm of 40-percent RH, you can expect roughly twice the rate of fading. If you store the film at only 15-percent RH, the fading rate is cut in half. Note that storing film at too low an RH can cause brittleness and excessive curl. Our recommendation for the best storage is at an RH between 20 and 30 percent. Other factors in handling and storing motion-picture film are covered later. However, if you are storing color motion pictures for long-term extended life expectancy, see chapter 3 for additional details.

The necessity for sealing films against moisture complicates their packaging and retrieval. You can minimize these difficulties by storing films in a vault that is temperature controlled to 1.5°C (35°F) at 20- to 30-percent RH. This kind of physical installation is expensive. An ideal practical means of storage is probably an air-conditioned room equipped with a fully automatic RH control.

To prevent moisture condensation on material taken from a refrigerator or freezer, allow the package to reach equilibrium with the room temperature. The warm-up time required depends on the temperature difference between the film and the surrounding air, the dew point of the air, the quantity of film, and the size and insulation of the packaging. Moisture condensation is not only harmful in itself, but can also lead to returning the film to storage in a high-moisture condition. Always recondition the film to be in equilibrium of 50 percent or lower before replacing it in cold storage.

Periodic inspecting of a random sample of stored film will determine the adequacy of storage conditions. Film custodians can use data of the type shown in the earlier temperature predictive statements to select a satisfactory condition for film based on two important decisions. How long do you want the film to last before it shows objectionable change? What is an objectionable change?

Important: Because data on expected changes at room temperature and lower are based on accelerated tests made under controlled high temperatures at 40-percent RH, you should use this information only as a general guideline on how a motion-picture-film product will actually perform. Additional information can be obtained from ANSI IT9.1-1989.

CHAPTER 5

Handling and Maintenance of Processed Film

Introduction

Handling of any sort depends on a certain amount of manual skill and accurate knowledge of the thing being handled and the reasons for handling it. It's in the handling and mishandling of the film that most damage occurs. This section concentrates on the rules for handling and maintaining film and the reasons for doing so in a particular way. We also offer a vocabulary of terms to describe various film injuries and distortions.

Motion-picture film possesses several unique properties. The support is optically clear so that the image will not be adversely affected. It is precisely perforated so that the placement of each successive projected-image frame will coincide exactly on the screen to prevent annoying image unsteadiness. Furthermore, film is thin enough to store large quantities on convenient-size reels and yet strong enough to sustain a great number of projections. Therefore, if you want to extend quality presentations, you need to make these special film-handling techniques familiar habits.

Film can be mishandled both physically and chemically. Much of what we deal with is clearly the physical kind of damage, from force applied inappropriately to defects in the storage and handling environments. Film handling is necessary, and it is often during inspection and cleaning operations that one may inadvertently cause damage that decreases the value, or even the usability, of the film. You must handle film carefully.

Room Cleanliness

Carefully look at the projection room and the inspection or storage area. Is it a clean, well-lighted place? Any lack of cleanliness can be magnified thousands of times during projection of the film on the theater screen. Dust and dirt deposits that escape detection become very distracting at that level of magnification.

Ideally, you should handle motion-picture film in a *white room* environment like that prevailing during its manufacture. But, in the real world, conditions may be drastically different, resulting in dirt that can lead to abrasion. You should assess your own film-handling situation by paying particular attention to the type and amount of ventilation, the materials used for floor surfaces, and possibilities for dust accumulation on the work benches and equipment. These are the main sources of dust and dirt that reach the film surfaces.

Modern equipment is designed to transport film hundreds of times without producing abrasion or dirt that are visible on the screen, but that equipment must be properly maintained and in good repair. You invite dirt and abrasion every time you handle film carelessly, fail to maintain the equipment, or let slip the cleanliness of the work areas. Motion-picture film, like many other plastic materials, has a tendency to build up static charges, especially under low-humidity conditions. When the film is charged during inspections or projection, dust and dirt floating in the air are easily picked up by the film. This is particularly true when you project film on today's almost-standard professional platter systems. High-speed winding across the bench top, while assembling a long roll or during inspection, is also a major invitation to these invasions.

Definitions and Inspection Methods

Buckle, warp, flute, twist, spoke, emboss, and curl are all types of damage that are caused when motion-picture film is pushed beyond its physical limitations during storage, handling, or projection.

Many different types of distortion are commonly referred to by projectionists and film handlers simply as warping or buckling. Film inspectors are often at a loss to understand the problem encountered by a projectionist because the condition is expressed in unspecific terms. Consider mastering the following specific terms for types of film deformations. You can help yourself and others—manufacturers, laboratories, exchanges, libraries, projectionists—to bring all the best in films. The more accurately you apply these descriptive terms, the more you assist in locating and eliminating causes of damage.

Here we describe conditions and characteristics of triacetate-base print films. Most of the conditions described also apply to ESTAR Base or other polyester-base films. In either case, careful handling helps keep films in top condition and provides audiences with superior screen images. Each description is keyed to an accompanying illustration.

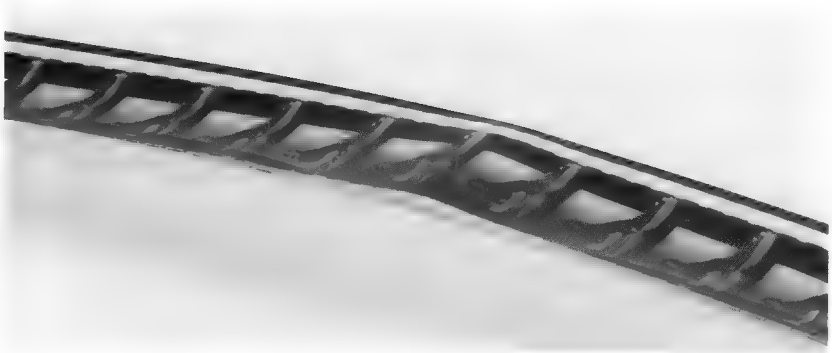


Figure 27

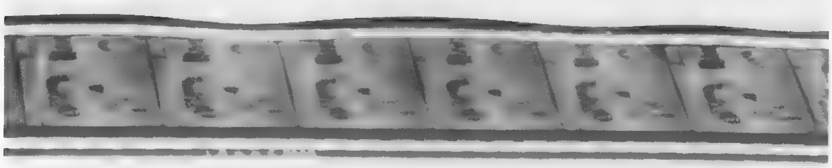


Figure 28

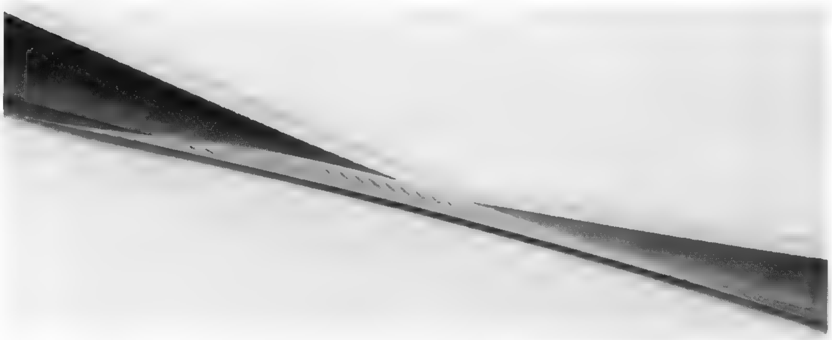


Figure 29

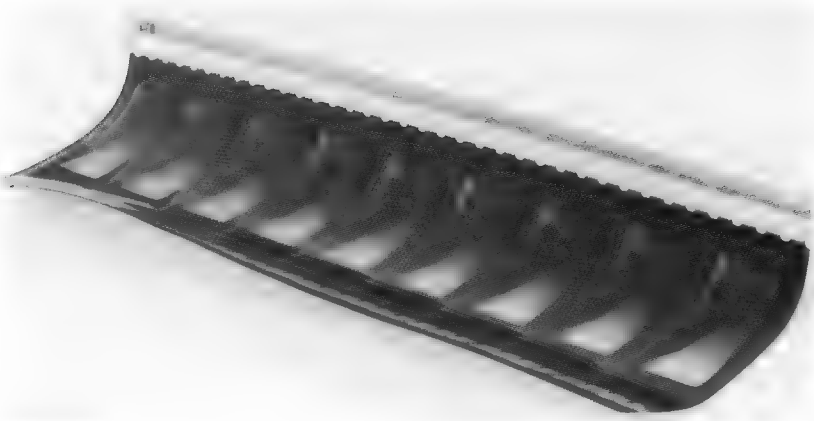


Figure 30

Buckle—occurs when the edges (along the length) of a film are shorter than the center (**Figure 27**).

Temporary buckle is caused by the loss of moisture from the edges (emulsion and base) when the film is stored in very dry air for short periods.

Permanent buckle is caused by the loss of solvent from the edges when the film is stored in very dry air for extended periods.

Edgewave or Fluting—occurs when one or both of the edges (again, along the length) are longer than the center (**Figure 28**). This is the opposite of BUCKLE.

Temporary edgewave or *flute* results from storage under moist conditions.

Permanent edgewave or *flute* results if a roll is wound under high tension or if one edge is stressed during film transport.

Twist—is caused by loose winding of new prints, emulsion-in, under dry-air conditions. If the film is wound emulsion-out under the same conditions, the undulations do not alternate from one edge to the other, as in the illustration, but are directly opposite one another (**Figure 29**).

Curl—the departure from flatness caused by dimensional differences between the emulsion layer and the base (**Figure 30**).

Spoking—is caused by loose winding of film that has considerable curl (**Figure 31**).

Temporary spoking disappears when the film is unwound.

Permanent spoking is seen as TWIST when the film is unwound.

Embossing—is a permanent deformation that occurs when prints are projected with high-intensity lamps and without proper heat absorbers. The excessive heat expands the picture area, and the frame stands out in relief. This distortion is usually not detrimental to the screen image because all film frames are equally affected (**Figure 32**).

Motion-picture film must be thin in order to provide a sufficient quantity for practical use on reasonable-size reels. It must also be flexible to negotiate the film path in some projection systems. If either of these characteristics was altered to permit more vigorous (or less than careful) handling, the practical uses of film might be seriously curtailed in existing equipment. The emulsion layer(s) that carry the image are only several tenths of a thousandth of an inch thick. While it is remarkable that a film emulsion can be resistant to scratches, great care is still necessary to prevent image-degrading abrasion. Your knowledge of handling and maintenance of film makes it possible for films to perform satisfactorily during their useful life.

Figure 31

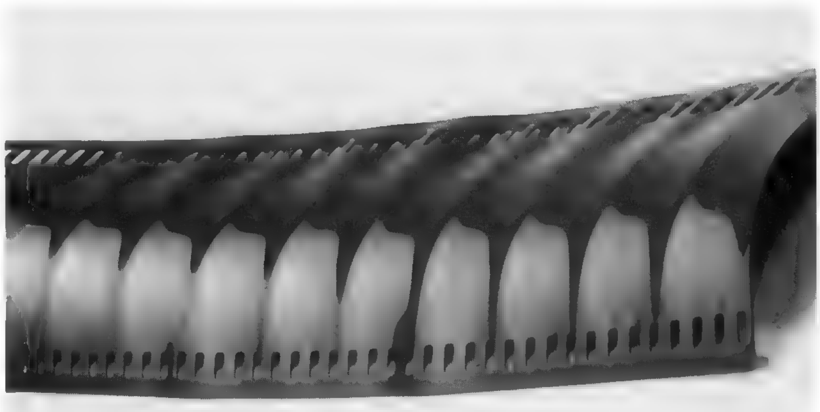


Figure 32

New Prints

In some ways, film toughens with use. The emulsion surface of newly processed film is a bit more susceptible to abrasion than film that has been in service. Therefore, when you mount new prints, be careful to avoid contact with the picture area, even while using proper gloves. Professional motion-picture-release prints are usually sent by the laboratories to a distributor as large rolls wound on 3-inch cores in lengths of about 2,000 feet. Each roll can be considered to be in pristine condition if it has been properly processed and handled in the laboratory. The distributor mounts the rolls onto 2,000-foot-capacity shipping reels for theater use. The projectionist transfers the film from shipping reels to *house* reels for projection or splices all the individual reels together for use on the platter-transport system or other systems that may be in use. Prints on 16 mm or 8 mm are usually mounted on reels at the laboratory prior to shipping. All prints, 8 mm, 16 mm, and 35 mm should be lubricated by the laboratory prior to shipping.

Generally, new prints don't need to be cleaned. But if you must remove lint or dust later, use a plush dampened with an approved film-cleaning liquid, and hold it lightly against the film as it is wound. Attempt this procedure *only* if adequate ventilation is available to prevent possible toxic effects. A 35 mm release print should be relubricated by edge waxing after cleaning; otherwise, serious perforation damage can occur, especially during initial projection. New 16 mm prints should be cleaned and relubricated using a film cleaner that contains lubricant.

Winding (Smooth Roll)

It is extremely important to wind film evenly and with sufficient tension to provide a tight roll. If the roll is not tight and smooth, it can suffer edge breakage during shipping and handling. When you rewind, be careful that the winding machine is properly lined up so that the film feeds smoothly and squarely from one reel to the other, leaving no protruding edges. With console-type motor rewinds, proper alignment should be part of the original design, but check the appearance of a wound reel to determine whether some further adjustment is necessary. If winding for long-term storage, always wind emulsion-in to minimize stress.

There are some winding habits that seem deceptively helpful. Is one edge of the film riding against the reel flange during the winding operation, as shown in **Figure 33**?

Some bench rewinds are deliberately set out of line to obtain even winding by this method. Occasionally, shipping reels are sprung so much out of shape, as illustrated in **Figure 34**, that you may again be tempted to achieve even winding by flange binding.

Figure 33

Figure 34

Historically, 35 mm release prints in the United States have been wound emulsion-out when ready for projection. In this orientation, the film comes off the supply reel in a counter-clockwise rotation but winds onto the projector take-up reel in a clockwise rotation with the emulsion in. When 35 mm film is kept wound emulsion-in exclusively, there is a tendency for reduced focus drift and other screen-image problems.

There is no preferred emulsion orientation for 16 mm and 8 mm films since they are used in both emulsion positions. Original reversal films, such as those used in cameras, are wound emulsion-out. Prints from negatives and reversal dupes are normally wound emulsion-in. And, because thermal-energy levels are only a fraction of what is encountered in theatrical projection, focus drift and other screen-image problems are not apparent.

The problem with the edge-binding method is that sharp points are sometimes left on the rims of some metal reels when, for example, someone used pliers to remove a reel of film from a tight shipping case. A sharp point of this kind may cut the edge of the film on each turn of the reel.

Sometimes reels are bent or sprung to less than or considerably more than the film's width. If so, the reel should be replaced. Much of the damage occurs when the reels are forced into shipping cases that are themselves damaged. If you must use defective reels and cases until replacements arrive, make every effort to restore them to a reasonably usable condition.

Note: Never tap the reel against a bench or wall to smooth out a poorly wound reel of film. If there is loose dirt on the film, it will lead to abrasion.

Inspection of the Film

Don't assume that film arriving from a distributor or library doesn't need inspection. Damage that can be diagnosed early and repaired extends the film's life and maintains the implied contract with viewers that films will be presented in their best condition.

The problem is not the intention or even the fact of inspection but the manner and place of some inspections. You are frequently rushed for time, so the inspection remains superficial. The fast winding of film creates dust-gathering static electricity; the heads and tails of the film get whipped across the bench or even the floor and pick up further abuse and dirt. The final insult is often that the splices you attempt are out of alignment or fail to register properly in relation to perforations, or simply are so poorly prepped that they separate the next time around. If a film breaks during projection, it may get mangled further, but it also means that viewers are annoyed, inconvenienced, or even deprived of their belief in the illusion being projected on the screen. The results are criticism from viewers and even a financial loss.

The two essentials of a satisfactory inspection are a well-designed inspection area and proper film handling. The area needs to be laid out so that all needed equipment, splicers, tape splices, cleaners, etc., are handy. Can the area be kept clean—floor, walls, ceiling, and especially work surfaces? The air must be free from harmful chemicals and the relative humidity should be at least 40 percent or higher.

Sight Inspection involves a careful look at the film. This way you may detect substantial defects or damage, like major scratches and color fading. But, even at its best, sight inspection is either relatively slow but thorough, or faster but somewhat more superficial.

Hand Inspection is really a gloved* inspection. The film is run between the thumb and forefinger (**Figure 35a**) as it is rewound. Sometimes inspectors hold it in the closed hand from above (**Figure 35b**) and apply pressure with the thumb and forefinger to cup the film. With this technique, if the other fingers are pushed upward, they may rub against the film surface and cause a considerable amount of abrasion—particularly if the glove is dirty.

While contact with the edges of the film is a necessary part of inspection, a little cupping is better than too much. Film should be run between the thumb and forefinger with very little pressure while remaining in contact. Bearing down can also develop a running kink up the middle of the film, particularly in low relative humidity. If the film is too dry or cold, it may even crack or split.

Ragged edges, perforation damage, and any physical damage on the surface will tend to snag the cotton glove. That's one reason for wearing the glove, but the other is that these same defects may nick the unprotected skin. Another reason for wearing gloves is skin oils and possibly other chemicals may transfer to the film and ruin it. Frequent changes and thorough washing of gloves are vital.

*Not all gloves are alike. Lint-free cotton gloves are the best choice. But gloves made from polyester or nylon are just fine if they do not generate static. For film editing, most editors prefer to work without gloves but are respectful of the film surfaces.

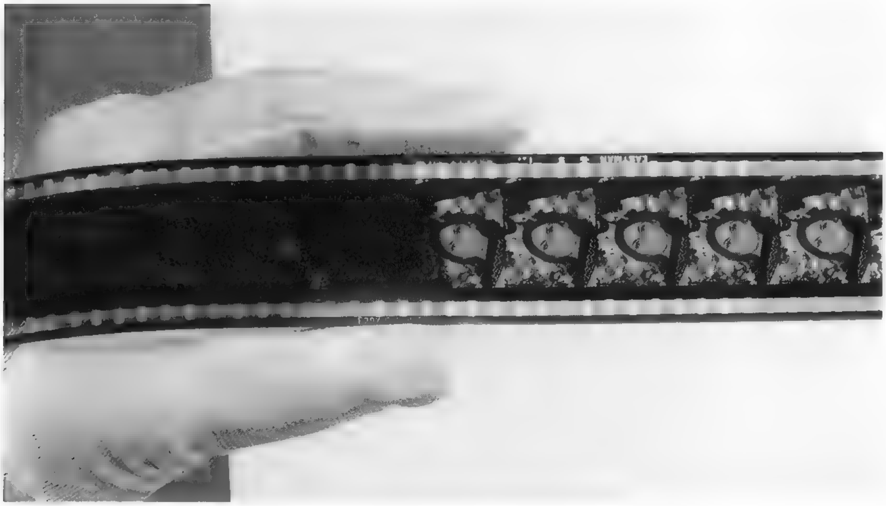


Figure 35a

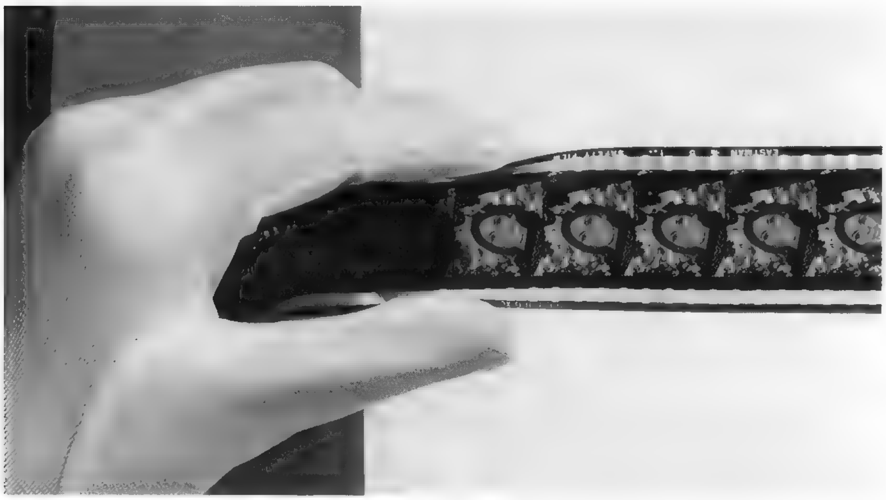


Figure 35b

Machine Inspection is done by specially designed equipment that transports the film by electric motors through a damage-detection system designed to stop the film when damage is located. While these machines relieve an operator to do other work, they require proper adjustment or they could become too sensitive or insensitive to do a good job. Machines must be tested daily because static-electricity build-up can generate static and attract dust and dirt. The best inspection is done carefully by hand.

Visual Inspection can be projecting the film and playing its sound track to be able to observe problems. But this type of inspection should only be done after hand inspection. Scratches, abrasions, burns, color shifts, and loss of footage can be detected this way. A bench-type viewer will also show picture damage. Even though visual inspection may be quite tedious, it will be worth the time to conduct on an occasional basis.

Splices and Splicing

Sometimes projected-film footage is coupled or spliced together. Splices are crucial, and a good splice is one of your key responsibilities as a film-handler. While an expert splice has long-lasting strength, many splices are simply not made that well. That is why the following material should be reviewed with great care, even if you have made hundreds of splices already.

There will always be someone who will try to splice film with almost anything that can possibly hold two pieces of film together. Certainly, generations of transparent mending tapes have been used, but so have other gummy tapes, even staples and maybe even safety pins. Film cements and specifically designed film-splicing tapes are the recommended materials, but they aren't always used as effectively as possible. Much of this work can be done successfully by handling, with great care, but there are also machines that help a lot, if properly adjusted and maintained.

Splicing is really an art. Splices have a direct bearing on the life of the film and the satisfaction that it brings viewers for entertainment or learning. To make a proper splice, we must be familiar with its mechanics and recommended procedures.

Where to splice is also very important. Sometimes the need is obvious when the film is broken. But we must also consider any area of film that shows structural weakness. If such areas appear in a very short piece of film, remove the entire length rather than make more splices. Removal may be less detracting on the screen if the continuity remains sufficiently intact.

Two of the most conventional types of splices are the overlap cement splice (**Figure 36**) and the tape splice (**Figure 37**); they're made between perforations or on the perforations with 16 mm film.

With acetate-base films, the overlap cement splice has generally been used for editing negatives, while the tape splice is more popular in projection booths. Since only special equipment will splice polyester-base films, tape is the choice here also.

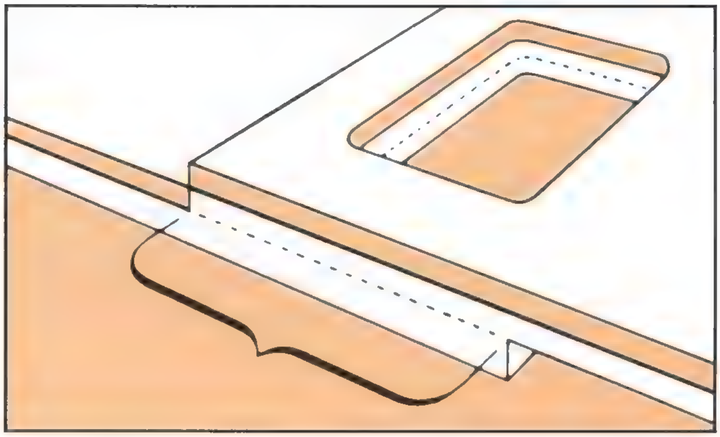


Figure 36

General Concerns

Historically, the most common film splice has been the overlap film cement. Those who work in theaters, film exchanges, or media centers are used to 16 mm splices made on a bench-top splicer that includes a perforation in the overlap area. With 35 mm splicers, the overlap is between the perforations.

The tape splice has become increasingly popular because of automated-projection equipment, where many splices are made during the feature presentation make-up. The tape splices are placed on both sides of the film, giving great strength, and are accepted because they don't sacrifice the picture frames as the cement splice does. During picture breakdown, the splices are peeled apart, leaving the entire footage intact.

Tape splices can be made either with an overlap or with the two film ends butted together. There is an esthetic (doesn't jump) and mechanical (makes no noise) advantage to the butt-type splice on 35 mm prints. The type of splicer purchased will determine the type of splice that can be made.

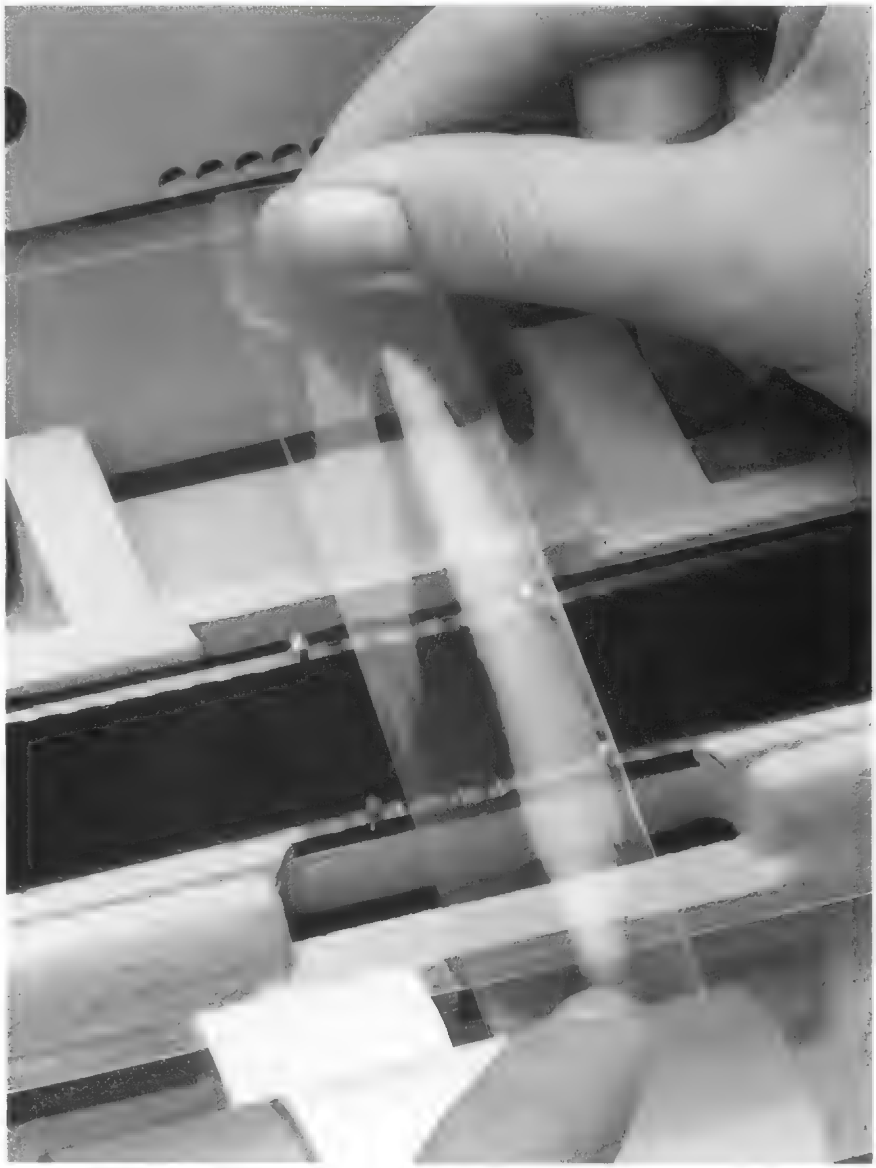


Figure 37

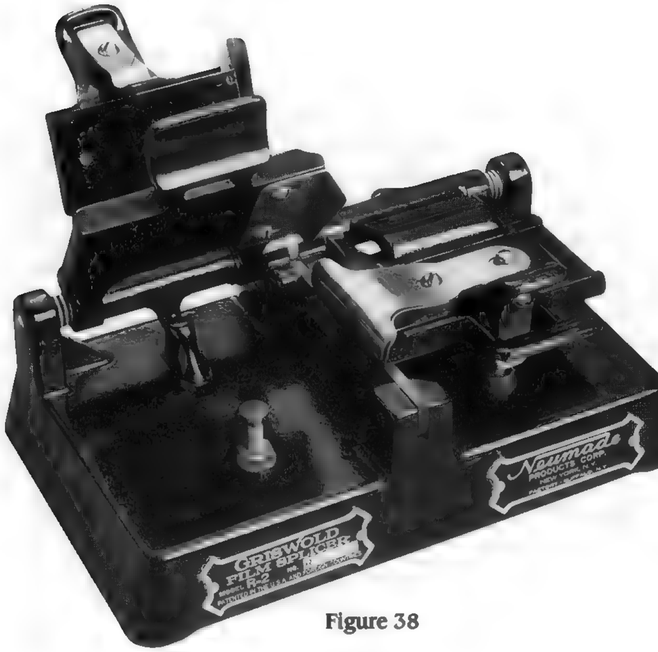


Figure 38


Figure 39

Making Cement Splices

Overlap cement splices depend on the solvent action of a suitable cement which essentially welds the two prepared film surfaces into one. You will find that SMPTE Recommended Practice, RP111 1989, specifies the measurements and location of cemented splices. Whatever solvent you use, be sure to follow the instructions carefully, have plenty of ventilation, and avoid contact with the skin.

Here's a quick review—motion-picture film is constructed basically of three layers: an *emulsion,* a coating that consists chiefly of gelatin in which a silver- or dye-forming substance is suspended; a *binder,* a microscopically thin layer between the emulsion coating and the base; and a *base* (or support), a flexible clear plastic material. In addition, some films have an antistatic- or antihalation-base coat or gelatin coat for added protection against extra, but not uncommon, hazards. Also, remains from any lubricants that may have been added to the emulsion or base will prevent the splicing cement from penetrating well enough.

To make satisfactory splices, you must carefully scrape off all emulsion, binder, and anything else from the base. Be careful to cut the film sections so that they will join in frame (the splicer usually will dictate this). You can remove the emulsion and binder layers from the splice area in several ways. With the widely used bench-top splicer (**Figure 38**), a combination scraper and wire brush works well. Another type of bench splicer (**Figure 39**), one that provides a rigid scraper blade that is drawn back and forth over the splice area to remove the emulsion and binder, makes excellent splices provided the scraper is kept sharp and correctly aligned. A more professional-type splicer is of the pedestal type, where the jaws are operated by foot pedals, but scraping is done similar to that shown in Figure 39. In any case,

when you have completely removed the emulsion and binder, you will see an evenly frosted scraped area (**Figure 40**).

The surface on the base side of the film you are joining must be thoroughly cleaned. Carefully scrape off the magnetic sound track, if there is one. Do not use film cement to remove the magnetic oxide as the solvent may leach into other parts of the track area causing damage. If the base surface contains even a slight film of oil, the solvent may not do its job of dissolving the acetate base. It may help to roughen the base surface if the base resists the cement. You may find it easier and more effective to apply a small amount of cement to the base side splice-area surface; then wipe it off immediately. This acts as a primer coating before the actual splicing operation, and it helps you get thorough adhesion of the two surfaces to be joined.

When the emulsion and binder are satisfactorily removed, apply the cement to the splice area. Use enough cement to wet the scraped area but not so much that it will run outside the splice when the two sections of film are pressed together. The splicer mechanism must be adjusted to provide uniform pressure across the width of the film. Give sufficient holding time (about 10 to 15 seconds at room temperature) under pressure in the splicer. Some splicers have heated platens that will reduce the drying time. Experiment for your particular situation. At the end of the bonding time, release the pressure and rub the finished splice carefully with a soft cloth to remove excess cement and to help seal the cut ends.

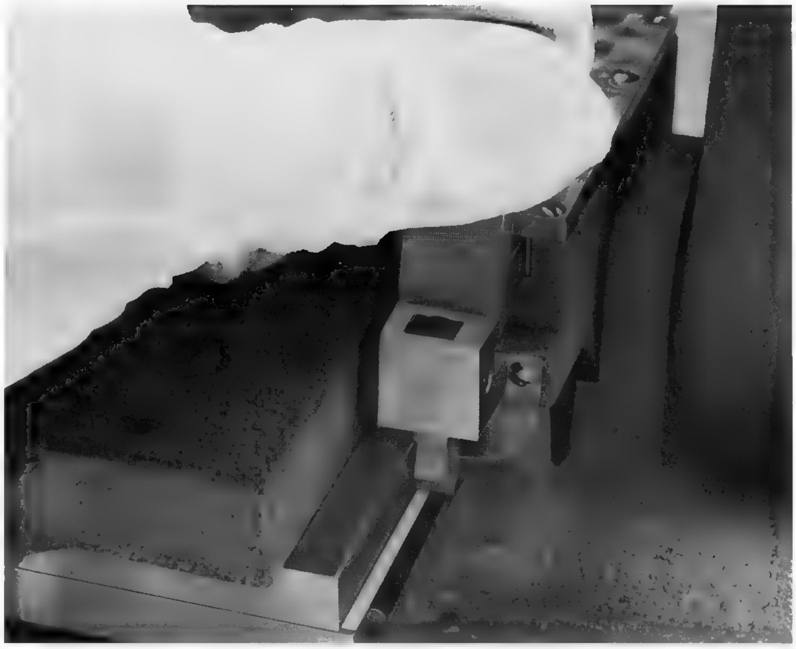


Figure 40

Figure 41

The parts of a good cement splice are welded and partly dissolved into one another. It is important to bring the two surfaces under pressure soon after applying the cement. Don't slam the pressure clamp into position. That will splash the cement. If you raise the left clamp of the bench-top splicer after applying the cement, it will be less apt to flow under the film, leaving a cleaner back surface, and it will dry more quickly. This will greatly reduce the possibility of distortion in the spliced area when the cement has dried. After sufficient holding time, you may test the splice by gently flexing the film as shown in **Figure 41**. Because a cement splice does not usually attain full strength for several hours, you must handle it carefully for immediate use. If the splice contains any bubbles or haze areas, the weld will be weak and may not hold.

Some Common Causes of Unsatisfactory Cement Splices—

- Using old film cement from which the essential solvents have evaporated. For everyday use, store film cement in small bottles that provide the least possible contact with air space.
- Allowing insufficient drying time.
- Not completely removing emulsion or binder from the scraped area, causing an incomplete or faulty weld.
- Scraping, scratching, or gouging the film base excessively, thus weakening the base and causing the film to collapse or break at the splice.
- Delaying too long in bringing the film ends into contact after you've applied the cement.
- Applying too much cement. Excess solvent action causes the splice to buckle. During projection, the splice may cause difficulty at the film gate or at the sprocket-pad roller.
- Applying too little cement, resulting in an incomplete weld. Such splices should be remade or they may come apart during projection.
- Aligning the splicer poorly. This causes misaligned splices which catch in the projector film path and tear apart.

Observing the following suggestions will make cement splicing easy and effective:

- Keep the splice clamped for at least 10 seconds (longer, if practical or in a cold room) after the film ends make contact. Insufficient holding time is a prime cause of early splice failure.
- Never add fresh cement to old in a work bottle. Start with new cement every day. Clean the bottle with a little fresh cement before refilling it.
- Keep the work bottle of cement tightly covered between uses. The solvent in film cement evaporates rapidly.
- Check the base side of the film for oil, dirt, or other deposits. Remove any base coating, preferably by applying and then wiping off a little film cement. Carefully scrape the base side to remove magnetic coatings.
- Keep the splicer scrupulously clean and in correct alignment. Use film cement to remove cement buildup and scraps of film shavings. Keep the cutting bar and all surfaces bearing on the film clean and sharp.

Making Tape Splices

If you make tape splices properly, they are extremely durable, but you can also disassemble them at any time, if necessary, without damage to the film. Tape splices are mainly used in theaters that make up large reels for automated-projection systems or adding trailers. If you use polyester-base films, you will find tape splices essential because they cannot be spliced with ordinary film cement. Tape splices are also used for splicing acetate to polyester. Definitive guidelines or standards for tape splices are not yet available,* but we offer the following procedures and recommendations based on experience and study.

You can make an overlap tape splice on a bench top like any similar cement splice, with one exception. Instead of using cement to bond the two film ends at the overlap, a piece of 35 mm polyester tape is placed over both sides of the film.

***The REEL PEOPLE Collection,* KODAK Publication No. H-50, includes a collection of the best how-to articles from the out-of-print Kodak newsletter *Film Notes for the REEL PEOPLE.* Topics include splicing techniques, projection practices, film handling and cleaning, and theater management.

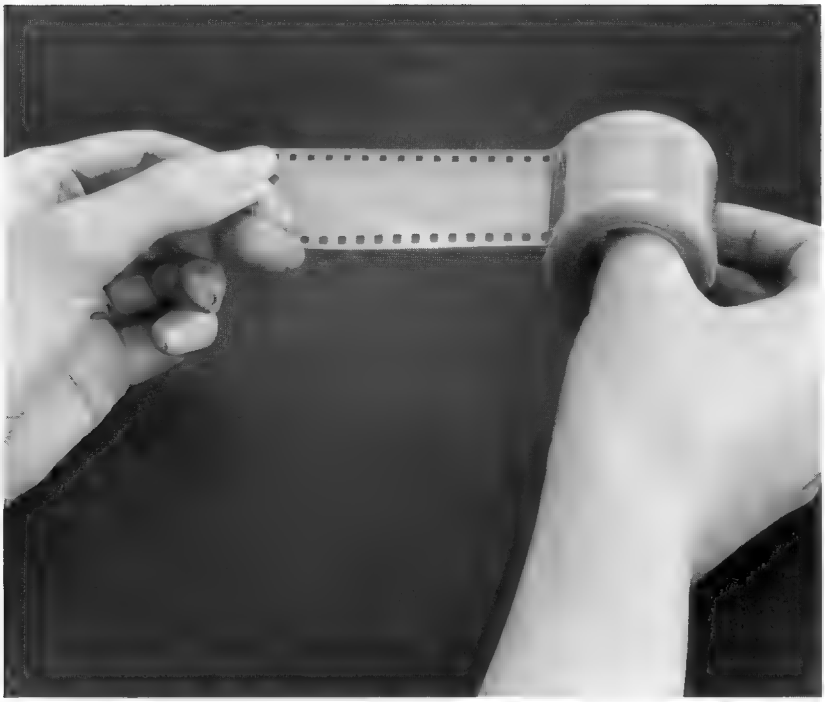


Figure 42

Figure 43

Splicing Tapes—Splicing tape is available in 35 mm perforated and unperforated rolls (**Figure 42**) and 35 mm tape tabs (**Figure 43**). These products are also available in super 8 and 16 mm. Be sure the tape is made with non-oozing adhesives, especially for splicing film. The main advantage of the perforated rolls is that the tape can be cut to any length for film repair probably at a lower cost per splice. It may be found that the longer roll is more difficult to handle than the *cut-to-size* tabs.

Unperforated 35 mm tape can be used only with special splicers, such as the one shown in **Figure 44**, that punch out the perforations in the tape area as the splice is made. Tape tabs, on the other hand, are quite simple to use, although somewhat more expensive. For esthetic reasons and added strength, you may want to make an overlap tape splice with tape sections two frames long (**Figure 45**), places the tape ends at a frame line (**Figure 46**) for invisibility during projection and provides for greater adhesive area.

Splicers—When making tape splices with a bench-top or block-type splicer, follow these important directions:

- Cut the two ends of the film to be spliced in the normal manner as would be done when making a cement splice or in the center of the frame line if a butt splice is to be made.
- You don't need to scrape the emulsion. After it's been cut properly, place the two pieces to be joined on the registration pins of the splicer. Register the perforation holes of the tab tape with the film and press. Remove the backing paper for the precut tabs one side at a time, or lower the perforating handle when you use unperforated tape. Repeat this operation on the other side of the film.

Figure 44

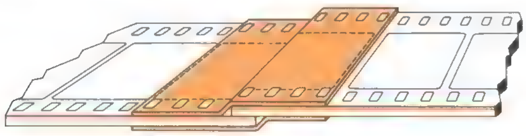


Figure 45

Figure 46

- If you do not have registrations pins, use a couple of small weights or magnets (if working on a metal surface) to hold down the film while applying the tape.

  Whatever you use, protect the film by putting felt or some other non-abrasive material between the film-contact surface and between the weights or magnets.

  Caution: Do not use magnets near films that have a magnetic sound track because of the possible degaussing that can occur. Use small weights instead.

  This procedure allows the use of both hands to place the tape in registration over the film. Remember, if the tape is placed on the film incorrectly and then peeled off, that piece of tape should be discarded because of the tight curl and peel marks that are usually produced by the peeling process. Under certain conditions, especially when static electricity may be present on the film, placing a raw tape on the splicing area can be very frustrating. In these cases, the extra expense for splicing tabs may be justified in order to save time and effort.

- Use a suitable solvent film cleaner (never use alcohol on acetate-base film), on a small piece of cloth to clean the film ends prior to placing the tape on the film. Use plenty of ventilation and caution with the film cleaner, as it may be considered toxic by some municipal or government codes.

  Remember, a properly made tape splice can be considered permanent, so keep it free from air bubbles and other visually distracting marks.

Some Hints on Making Good Tape Splices—In the event that a tape splice must be disassembled, use your fingernail, or a similar object, to gently lift the corner of the tape to facilitate peeling. To prevent the possible tearing of the film or tape, hold the film with a finger at the corner where the tape was lifted, and peel the tape slowly away

from that area. The tape remaining on the other side can be removed by repeating the same procedure or by carefully twisting the film ends and peeling the film away from the tape.

- Scraping the emulsion is not necessary if an overlap splice is made.
- Never allow any part of the tape section to hang over the edge of the film. Trimming the excess tape will do little good because the overhang signifies misalignment at the perforations. Remove the tape and start again.

A butt/tape splice is considered somewhat superior to an overlap tape splice only because it is less noticeable (and possibly less noisy) on screen. A properly made butt splice depends on a precise cut on both film sections. Mate the two cut edges perfectly and hold them in rigid contact while applying the splicing tape to both sides. If either requirement is not met, the splice will be prone to hinging, or it will collapse during projection. A butt-type splicer definitely should be used for professional results.

No matter which type of tape splice is employed make sure that the film surfaces in the area of the splice are clean and free of oily deposits. Dirt causes bubbles and blemishes while oily film prevents proper adhesion. If the tape splice is not aligned properly or produces wrinkles, carefully lift a corner with a fingernail, or similar object, and peel the tab off; then replace it with a new tab.

Important: *Do not apply tape only between the perforations and in the picture area!* The protruding corners of the film edge could catch at a sprocket-pad roller and cause damage.

In review, it is important in all phases of splicing, cement or tape and of any millimetre, that you pay close attention to cleanliness, technique, and splicing materials. Relaxation in any of these areas can cause film damage and interruption of the presentation.

Film Damage

Types of Damage

There are countless ways to damage motion-picture film. Much of the damage is repairable, but careful analysis of it must precede any such repair. Useful communication about the damage is helped by an agreed-upon vocabulary. The following sections are an effort to establish some common understanding and terms for that purpose.

Abrasion—Scratches that we call abrasions can be found on both the emulsion and base sides of motion-picture film. In the image area, abrasions are recognized as any disturbance not normal to the picture area. These may be longitudinal or transverse scratches or very small cinch-type marks caused by the action of embedded dirt somewhere on sliding film convolutions in loosely wound reels. During rewinding, handling, and shipping, the loose film convolutions can slip against each other to cause abrasions. Continuous scratches along the length of film (**Figure 47**) are generally caused by external means such as contact with equipment components, or dirty and worn rollers in the film path. Regardless of the cause, excessive abrasions in the film image can distract from the film's created illusion and cause distracting noises in the optical sound track.

Emulsion abrasions (more on this later) on color film are less tolerable than base-side abrasions. If there are a few fine black lines with little sign of emulsion damage, they may be described as minimal base damage. Heavier and more frequent lines could be described as moderate. Major abrasion damage would exhibit many lines and would probably be present throughout the reel. Scratches are severe examples of abrasions. They physically damage the surfaces of the film and can cause the removal of a print from service.

Figure 47

A scratch the width of a human hair will project on a 6-foot screen almost ¾-inch wide with super 8, ⅜-inch wide with 16 mm, and nearly ¼-inch wide with 35 mm films. A scratch is a single definite line.

Again, scratches can be found on the emulsion or base side. Base scratches show up on the screen as black lines, because light shining through the clear base layer is refracted by the uneven surface of the scratches. Emulsion scratches on black-and-white film normally appear as black lines on the screen. On color film, a very light scratch on the emulsion generally appears neutral. But going deeper into the three color layers, it will project as most any color depending on the scratch depth, or even white if all the emulsion was removed. Scratches are best detected by visual observation on projection.

A few emulsion scratches can be tolerated if they do not materially detract from the film presentation. No scratch is desirable, but short, light intermittent scratches can be regarded as minor. Heavy scratches on either the base or emulsion should be cause to consider replacement of a print.

Minor base scratches can sometimes be rejuvenated, but heavy scratches usually mean replacement of the footage or withdrawal of the film. The presence of scratching should lead you to investigate all aspects of the operation—rollers, gates, handling room, and any equipment with which the film comes into contact.

Perforation Damage—Most perforation damage is caused by the film users (**Figure 48**). Perforation damage is often found on the first few feet of film, because it frequently results from improper threading. When you inspect the perforations through a magnifying glass or pass the film through your fingers, you will often find damage progressing from cracked, chipped, or elongated holes to torn holes. With severe damage, you will find holes that are torn completely through or even missing from the perforated film edge. Some perforation damage can be repaired with perforation repair tape, but major damage must be spliced out.

Your best bet for avoiding perforation damage, in addition to proper threading and a sufficient loop, is to be sure that the film isn't brittle, that it's properly lubricated, that damaged film reels are not producing a jerky take-up action on the projector, and that your projector sprocket teeth and pull-down claws are not worn out.

Edge Damage—A nick, crack, cut, or tear (**Figure 49**) to the edge of a motion-picture film greatly increases the film's chance of breaking. Film damage must not go unchecked. The leading causes of edge damage are damaged film reels, wobbles from bent spindles, and dry or brittle film. Nick for nick, convolution after convolution, the reel's damage transfers itself to the edge of the film.

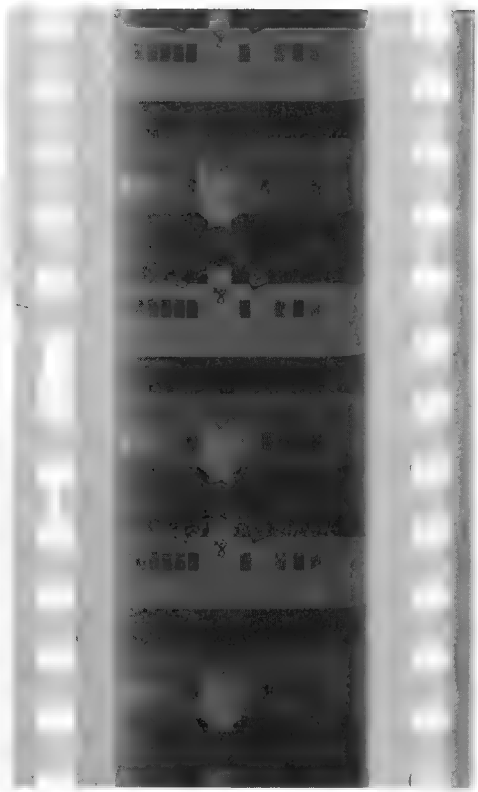


Figure 48

Figure 49

Replacing damaged reels is the best preventative measure. Careful tape splicing is your best repair. Edge damage obviously threatens the sound track as well as the image. If the damage can fit comfortably under the splicing tape, and if the film doesn't show signs of physical distortion, creases, or wrinkles, a perforated tape may be applied over the damaged area without removing any frames. Anything too extensive must be completely replaced.

Breaks—Breaks leave the film in two or more pieces (**Figure 50**) that should be joined together. Film separations can be caused by dry, brittle, shrunken film, poor splices, or by mishandling of film and/or projection equipment. When a break is repaired, be sure that the next break is not built in by inadequately preparing or misaligning the splice. If a film keeps breaking for whatever reason, it eventually begins to lose sound and image segments and becomes very distracting. Those gaps are clear clues to carelessness or stretching a product beyond its physical limits.

Surface Contamination—Soil, minerals, and oil are greatly valued, but not on motion-picture films (**Figure 51**). Films can become contaminated by mishandling and a lack of cleanliness in work areas. Coffee, sodas, glue, and other perfectly useful substances will soil film permanently. We alone can guard against the assault of these substances on film.

Color Shift—Capturing earth's rainbow in the dye layers of motion-picture film is a modern miracle. State-of-the art color film carefully processed, handled, and stored is hardly a fly-by-night phenomenon. Considerable longevity is built into the product, but it still demands the best from each of us in the film-handling chain.

Color shifts in a projected print are usually caused by something other than projection or film handling and are most likely due to misprinting.

If a radical color shift is noted for any reason, the decisions about replacement should reflect how crucial the color content is (in art and medical films, for example), the degree of fading, the standards of viewers, the film's potential use, and the budget.

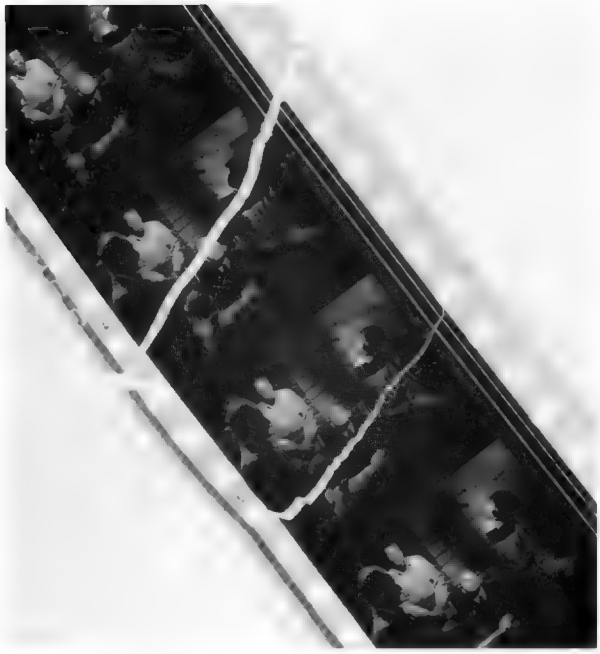


Figure 50

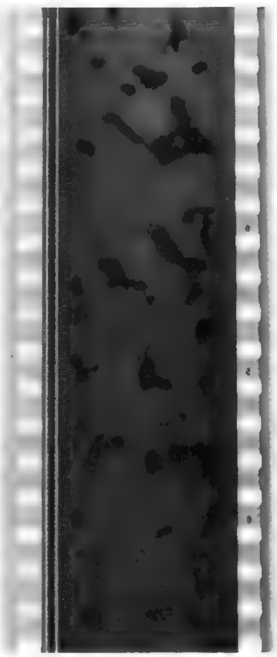


Figure 51

Figure 52

Creases—A crease is defined as a distinct sharp fold-line or crack in a piece of film. We should always splice out a sharp crease because it can lead to further film damage and screen-image deterioration. Creases and folds often occur in leaders and trailers, particularly when poor winding, untaped film ends, use of inadequate reels, or some other film-handling deficiency spills film onto the floor.

Blistering (Burns)—Very much like human skin, film burns start as swellings, grow into blisters, and then progress to the destruction of film. A burn spot on the surface of the film causes the emulsion to get hard and crusty and may easily separate from the surface of the base. The base may also become distorted and brittle. Extensive burn damage must be removed. The stopping of the film in a projector, even for a short time and for any reason, will cause film burns. Equipment malfunction is the cause.

Sprocket Marks, Visual Damage—Sprocket marks showing along the edge of the film will be very distracting, just like scratches (**Figure 52**). Sprocket damage shows more on the emulsion side than on the base because in most cases some emulsion has been removed, leaving colored or white areas. The usual cause for sprocket damage is faulty threading, misaligned splices, worn or misaligned parts in the projector, or some similar projection deficiency. Severe damage should be removed.

Sprocket Marks, Sound Track—The perforations of a 16 mm sound film appear along only one edge. Given a silent projector with sprockets containing teeth on both sides, you can see how it is possible, maybe barely, but possible nevertheless, to pass the sound film through a double-sprocket projector. This results in the projector trying to punch perforations where the track is. Even though there may be damage in the sound-track area, it may not severely affect the sound, and the damage should be removed only if continuity is seriously impaired.

Brittleness—You can't restore a brittle film to its original quality. Acetate film that has lost much of its moisture and solvent becomes brittle. Much of the moisture can be restored by proper storage and rejuvenation, but it's probably only temporary. Polyester films are more resistant to brittleness.

Brittleness can be generally recognized when it's no longer possible to bend the film over sharply on itself (with the emulsion on the outside) without having the film snap or break. On old nitrate films, the film would probably break regardless of the bending orientation. Since shrinkage often accompanies brittleness, the film perforations may also fit more snugly over the pins of film splicers and other similar devices that may cause damage to the perforation edges. Because you may damage the film, make these simple tests only at the beginning of a film (not on the leader) where such damage will be less noticeable. Whenever you notice many splices or considerable edge damage in a film roll, you should be alert for brittleness. You may also observe that the section of film normally stored on the outside of the reel is often more brittle than the film towards the center because the outside convolutions have been more fully exposed to the atmospheric causes.

Degrees of brittleness range from the slight amount in which the fold can be reversed without breaking or cracking the film, through signs of cracking or breaking, to the extreme case in which the film snaps, perhaps even before being folded. A brittle film may already be scheduled for retirement because of other damages and losses. Extremely brittle film should be withdrawn from circulation, whatever its apparent wholeness, because it's very likely to break, more than once, during projection. But, with care, it can be duplicated successfully to make another copy.

Shrinkage—Film shrinkage cannot be fully recovered. That fact is troublesome because perforations are carefully placed along the length of the film, and any change in their spacing can become a problem. As with brittleness, the loss of moisture and solvents in the acetate base is the root cause. Again, polyester is less susceptible to moisture loss and has no residual solvents. You can often replace lost moisture by proper conditioning and storage; you cannot restore solvent losses. Therefore, you must be concerned about any storage or handling condition that leaches either moisture or solvents from the film. The earlier discussion on proper storage conditions in chapter 3 can be your guide.

You may notice shrinkage because the film does not fit properly over the registration pins in the film-splicing block (**Figure 53**), or because it resists threading. You can determine the extent of shrinkage only with precise measurements. Films are not considered acceptable for projection with more than 1-percent shrinkage for most projectors.

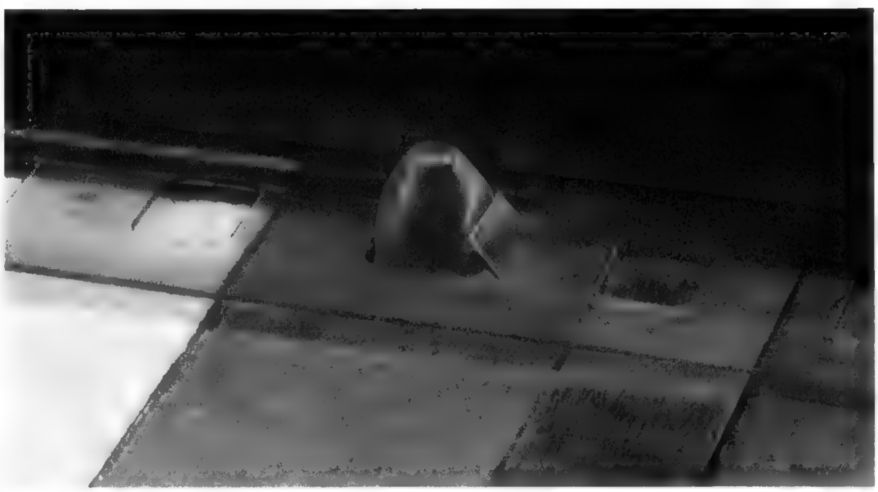


Figure 53

Emulsion Deterioration—Emulsion deterioration results from fungus, mold, and mildew. These micro-organisms attack the organic part of the film emulsion especially at relative humidities above 60 percent.

Fungus and mold are most often found on the emulsion side as dull spots or irregular areas. The spots increase in size and number if you leave them unattended. Eventually, they can deteriorate the emulsion to the point of uselessness.

In the tropics, fungus is especially a problem. These growths are most common in the summer in temperate zones that have a drastically high relative humidity. Rain or snow that wets the film may also set up conditions that encourage fungus to grow.

Growths are often found at the beginning of film rolls between loose convolutions. In extreme cases, the emulsion can be soft and sticky. Handling film in this condition is very critical and care must be taken not to damage the emulsion further.

After first examining for tackiness (and the film must be dried if tacky), it must be thoroughly cleaned to remove all possible surface fungi. After that, you may encounter anything from a slightly mottled image, to the beginnings of slight deterioration, to excessive visual distraction and softened emulsion. You must judge if the projected image passes your standards, but you should splice out major damage.

Common Repairs

Probably the most all-purpose approach to repair is a good fundamental cleaning followed by careful splicing. Let's look at some aspects of the latter.

Removing Footage—Removing damaged footage from a film without replacing it often involves an esthetic decision. Presumably, every foot of furnished film is there because it contributes to the total message. Therefore, simply extracting damaged footage may have noticeable consequences; the story punch line or other key phrases may never be known.

Film sections that are seriously damaged or footage with garbled sound must be removed. Any removal of film footage in education, in any kind of serious exposition, in musical presentations, and in carefully wrought dramatic films, can be a crucial loss. Don't splice out footage lightly. It is far better to avoid the need to remove any footage by careful maintenance and storage.

Nevertheless, we will find times when footage must be removed because it truly distracts or because the damage is such that it may lead to further damage. Before removing that section, consider the effects on the continuity and the future uses of the film. View the film to check the impact of the cuts on sight and sound. Missing footage that exceeds 6 feet should always be replaced. Always keep maintenance records on any footage removal.

Replacement Footage—There probably will be a time when you have a film that just doesn't seem complete with a particular chunk missing. Most distributors will sell replacement footage at a relatively modest cost, but the minimum orders may be for more than 100 feet. Also, delivery time may not be very timely. Before ordering replacement film, consider the physical quality of your print. Is it worth replacement footage in terms of its abrasion, color quality, number of splices, and so on? And, is the film used often enough? Is there a better version?

In ordering replacement sections, be very precise about what you need. Measure the film exactly from the beginning including credits. Replacement footage is identified by stating the footage numbers where damage begins and ends. It is advisable to order extra footage on both ends of the replacement section to compensate for splices and short sections that have been removed. Here is where the maintenance log comes in, because removal of extra sections could make the measurements incorrect.

If you need to use a damaged reel of film, remove the unusable section, replace it with a short section of leader, and keep careful track of how much film you cut out. The leader marks the spot and allows you to run the film without further damage.

Perforation Repair Tape—Perforation repair tape (**Figure 54**), a thin, narrow and very flexible strip of polyester-base adhesive tape with perforations identical to those of the film. When applied over damaged perforations with a specially designed machine, the tape makes a strong bond which is quite resistant to cleaning solvents and temporary high temperatures.

Before using any of the tape, instruct yourself carefully in the proper operation, adjustment, and maintenance of the perforation repair-tape machine. Also, remember that dirt and dust tend to collect on the edge of the tape. Even though it is a good but somewhat expensive product, the tape may still shift in time, and it is not as stiff as the film base.

Do not apply more than 10 feet of perforation repair tape for permanent repair and be sure to apply it to both sides of the film. Seat it thoroughly by drawing it between a cotton-gloved finger and thumb.

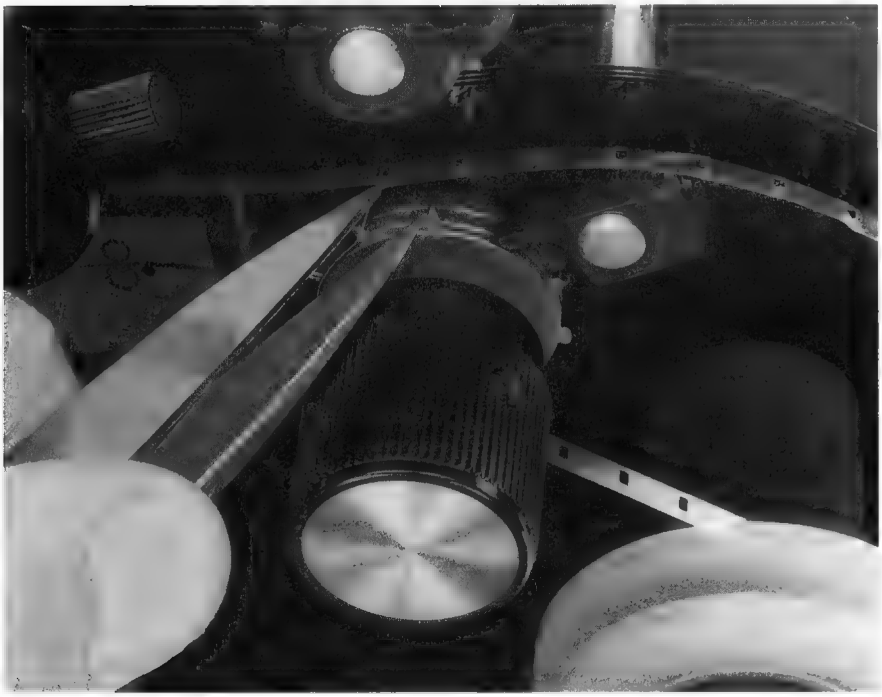


Figure 54

Blooping Tape—Blooping tape is an opaque adhesive tape designed for the deletion of sound errors, improprieties, and poor sound. In lieu of the older blooping ink, it can also be used to eliminate the annoying snap usually associated with splices. When blooping tape is applied over the sound track (at the junction of the splice) in a triangular or semicircular pattern, the photo cell or diode response is both attenuated and then increased gradually so that no audible noise is heard.

Notching and Trimming—Notching and trimming out certain types of film damage (**Figure 55**) is a bad habit that should be avoided because much of the film strength lies in its full width up to and including the edges. Notching and trimming reduce the film's ability to resist tears and increase its chances of catching in a projector.

Figure 55

Film Damage Evaluation

Failures of communication between you and others with whom you deal in handling a shared film, put that film at hazard. Imprecise or incorrect terminology, as we have emphasized here, is one such failure, but another is simple lack of communication. If you don't tell anybody about the bad sound or the large number of splices, you seriously reduce the chance of having these problems corrected and contribute to film breakage and viewer dissatisfaction.

In film exchange and library operations, a feedback form is a very important source of such information, but only if everyone who handles the film takes it seriously. Have we answered all your questions? Did you check the film reel and shipping identification systems? Will it always be clear what reel it is? Where should it go next?

Discard, Replace or Repair?—You can replace buckled and misaligned splices with new splices. Also, you can ruin film by poor splicing. Splices that are wide, stiff, buckled, or out of alignment can cause the film to jump the projector sprockets and tear the perforations or break the film. Perforations next to these splices are generally subject to strain and eventual breakage.

Repair or replace any long sections of a print that are structurally damaged or show heavy abrasion. Before removing long sections of film from the reel, determine whether replacement footage can be ordered and whether the remaining use of the print warrants the expense. Replacement footage does cost money, and somewhere along the line, someone will pay, whether it's a direct charge or increased cost of rental.

During regular inspection and checking, do not neglect to check the protective leaders and trailers. Keep them at full length to aid the projectionist in proper threading for smooth changeovers from reel to reel. A 1000-foot roll of this leader-trailer replacement film will cost less than other subject matter replacement film.

There is no clearly defined rule of what to discard or replace. The following are some suggestions that you can use as a guide. However, the presenter is the ultimate judge.

Missing footage. If there is no visual or sound loss of continuity (usually 5 frames or less), then replacement isn't needed.

Visual distractions. The length of time that visual damage remains on the screen is important. A distraction of 10 seconds or longer is considered major, and rejuvenation or replacement should be considered. If it is barely perceptible and not visually distracting, it is minor and probably acceptable.

Sound distortions. Same criteria as for visual distractions.

Perforation damage. How much has been repaired, and what is the potential for film breakage? This should be quite easy to evaluate, but, if in doubt, you should replace or discard the footage.

To discard, replace, or repair film takes a lot of personal judgment and should be carefully looked at from the viewer's perspective.

Film Winding

Rewinding

A skilled filmhandler strives for efficiency and effectiveness. During the manual rewinding process, don't constantly change the winding speed, or allow loose laps of film that can easily produce distracting cinch marks. If rewinding manually, keep enough constant tension on the supply reel to make sure that individual film convolutions will not slip on each other. Align the rewind stands to provide a smooth wind on the edges of the film. Protruding film laps can be damaged in shipping cases or by reel flanges that push against the film roll. If the rewind spindles are bent, it may be nearly impossible to wind a smooth roll unless the film is handled against one reel flange. We stated the reasons for not using this method earlier in this book. But, if this method is used, always make sure that the flanges are absolutely free from burrs or nicks that can damage the film edge.

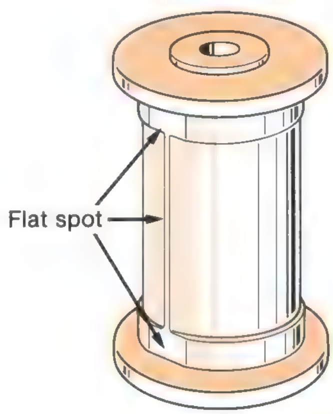


Figure 56

Winding Down

Motorized bench-top film-rewinding gear is fairly simple to operate. The film travels directly from the supply reel to the take-up reel. If you're inspecting during this operation, be sure your gloves are oil and grit free. Change them frequently and hold the film in the recommended way to avoid film abrasion.

For a console-type rewind, check the idler rollers to see that they rotate freely. Rollers can bind and the constant friction caused by film passing over them at high speed wears them flat all the way across (**Figure 56**).

The abrasion caused by film passing over a flat roller can be extensive, especially on a new print. Check rollers frequently and be sure that they turn freely and are properly lubricated. If a roller has developed any flat spots, replace it, even if it does seem to turn freely. No matter what type of rewinding equipment is used, be sure that continuous tension is maintained on the supply reel. Loose laps of film can easily cause cinch marks or kink damage (**Figure 57**) during abrupt starts or stops.

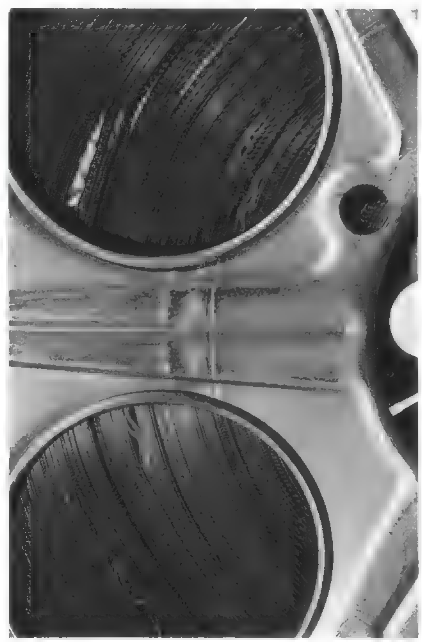


Figure 57

Film Cleaning

Solvent Safety and Static Electricity

Spinning film reels can build up static electricity which sends out powerful invitations to any dust or dirt in the work area, especially when the relative humidity is low. This buildup is also particularly prevalent in the large platter systems. There are antistatic devices that can be used, but the essence of prevention lies instead in being sure that work areas are as clean as they can possibly be.

Film cleaning at the theater, the library, or at the film exchange should be concerned with the removal of dust and other loose particles, gritty dirt, and oil mottle. All of these lead to minor film-base scratches. There are some relatively simple cleaning devices that can do this job adequately, but, for occasional cleaning, many choose the simplicity of moistened, soft, lint-free pads. These wet cleaners lessen the chance of abrasion from gritty dirt particles that build up on a dry cloth during the cleaning process.

Before beginning to clean any print (or negative), try the technique on some expendable film and check the results with a magnifying glass. Additional surface abrasions may be caused by cleaning if not properly done.

A Word to the Wise: *Verbum sapientia sum est* is the Latin translation for our warning. The form of advice may be ancient, but some of what we're warning you about is very serious.

There are some liquid film cleaners that are hazardous and flammable; most film cleaners are toxic. Some may even be banned, so local codes must be examined before their use. All directions must be closely followed, especially adequate ventilation, and prolonged or repeated skin contact must be avoided.

Figure 58a

Figure 58b

Non-solvent Cleaning

A *dry* method of cleaning incorporates a specially developed material that picks up dirt, dust, hair, and other unwanted particles from the film by contact with one or more Particle Transfer Roller(s) (PTR). The PTR is made from an inert polyurethane—with no adhesives, silicones, or leachable plasticizers and is environmentally sound, unlike the liquids. It has a 95-percent average-cleaning efficiency and can, itself, be easily cleaned with soap and water. It is available from FPC Inc., 6677 Santa Monica Blvd., Hollywood, CA 90038. Telephone (213) 465-0609.

Cloth/Solvent Sandwich

Thoroughly moisten (but not dripping wet) a pad of deep-pile, lint-free plush with an approved film cleaner and fold it around the film (**Figure 58a**). Draw the film through the sandwich of cloth (**Figure 58b**) at a speed that is slow enough to allow the cleaner to evaporate before the film reaches the take-up reel.

Winding up wet film causes spots and blotches. If ceiling space permits, you might consider installing an idler roller above the cleaning station to provide a longer film path from the cleaning cloth to the take-up reel, thus enabling the winding speed to be increased. As the cloth begins to dry, or when a complete layer of cleaning solution can no longer be seen on the film surface as it emerges from the folded pad, stop, refold the cloth to provide a clean surface to the film, add more cleaner, and resume winding.

Be sure to wear plastic or rubber gloves to protect hands against the solvent's ability to draw the natural oil from the skin. If a print must be cleaned, remember that the film-cleaning solution can remove the lubrication from the 35 mm release print. Film-cleaning solutions containing lubricants are not adequate for the lubrication of 35 mm prints but are used for 8 mm and 16 mm prints. It is important to lubricate 35 mm prints by edgewaxing prior to use and after cleaning. In all but an emergency situation, film can best be cleaned by a laboratory where suitable cleaning machines are available and proper techniques are used.

Investments in Clean Film

The material cost for cleaning an average release print is quite reasonable. But considerable time may be spent if the rewind-cleaning method is used. It's a good idea to recognize all the requirements for doing a proper cleaning job before actually attempting it.

To illustrate the complexity and importance of film cleaning at the professional level, **Figure 59** shows an ultrasonic film-cleaning machine that can remove even some of the deeply embedded dirt that is usually found around splice areas, although it cannot remove all of it. Other equally sophisticated film cleaners may use different operating principles, including PTR rollers, but their functions are still the same.

Figure 59

The only real solution for dirty, oily, and scratched release prints is to realize that most of the problems are caused by people and that it's up to us to assess and correct our contribution, if any, to these problems. Properly handled release prints projected with equipment that is conscientiously serviced and maintained can easily achieve 1000 or more runs without the need for cleaning or repair (more on PTR use on projectors later).

Film-Cleaning Checklist—Here are some things to remember when cleaning films:

- Use only well-known, high-quality film-cleaning solutions. Do not use alcohol of any kind because some types can soften the emulsion, or the base, and can increase the risk of abrasion during the cleaning process. Alcohols are not good oil solvents because they can remove magnetic striping, are highly flammable, and can lead to moisture condensation.
- On film with magnetic tracks, first check the cleaning solution on a short section of film. If a brown color appears on the cloth, stop! An approved film cleaner is suitable for use with most magnetic striping, provided contact is brief.
- Use a soft, lintless cloth such as a deep-pile plush. Avoid using hard-surfaced textiles or exerting excessive pressure on the cleaning pad as these tend to abrade film and hold any grit in contact with the film surface. Also, do not use cloths from which dyes bleed. Fold all cut edges inside the pad to prevent depositing lint on the film.
- Refold the cloth pad frequently so that a clean surface is always in contact with the film. Advance impregnated dry-tape webs frequently for the same reason.
- When cleaning with cloth pads and solvent, wear protective gloves and make sure there is adequate ventilation in the work area (see Caution on this page).
- If you need to clean a 35 mm print, be sure to relubricate it properly by edgewaxing, because cleaning solvents remove the lubricants along with the dirt.
- Make sure that the film-cleaning solvent is evaporated from the film surface before you wind the film onto the reel or core. Place some sort of lamp on the table so that it will reflect light from the film surface as you clean. This way, you can observe the solvent on the film and the point where it evaporates.
- To speed cleaning, lengthen the film path between the cloth pad and the take-up reel. Use idler rollers near the ceiling or place the reels far apart. Remember, the faster the film is wound, the more frequently you will need to replace the cleaner on the cloth and rotate the pad. Never let the pad become so dry that wet cleaner is no longer seen on the film surface.

A cleaned print will remain that way only as long as the contributing factors that cause dirt problems are known and remedied—or prevented. To begin with, oil acts as a lubricant when applied to bearings and other mechanisms to reduce friction and wear. Otherwise, oil on film acts like a magnet, drawing dust, dirt, and gritty particles to the film surfaces and keeping them there. Oil can come from an over-oiled projector, worn bearings, or from inadequate or improper equipment cleaning. In every case, the oil finds its way to projector-component surfaces that come into contact with the film. Once on the film surface, oil continues to migrate and film mottle develops. Contact with dirty surfaces and airborne dust and dirt, with the help of static buildup, does the rest.

General Guidelines

Try to do the best you can to prevent dirt buildup in the work area. If cement splices are made, be sure the film particles from scraping are cleaned away from the film before it is wound up. Also keep the splicer and bench top clean. Dirt particles that look like large chunks of debris on the screen are almost microscopic in size when viewed on the film surface. You can't see most dirt particles on a bench top with the naked eye.

Not a Cure-All

Simple film cleaning does nothing to eliminate scratches and cinch marks because all such marks are actually forms of physical damage to the film surface. Therefore, preventative maintenance and cleanliness are the keys. Once the damage is done, efforts to recover a print can be very expensive and can produce results that are only marginally satisfactory. A film will look best to viewers if it has been properly cared for and has always been in a clean environment on carefully maintained equipment.

Lubrication

All motion-picture films destined for projection are required some level of lubrication. The lubricant incorporated in some 8 mm or 16 mm films may be sufficient, even after processing. Since all films may not be lubricated, it should be done to assure a smoother projection. Most laboratories do apply a lubricant when necessary.

Caution: Solvent film cleaners or lubricants require adequate ventilation and avoidance of prolonged contact with skin. If these precautions cannot be met, employ a professional firm to clean and lubricate the films. Also, local municipal codes must be strictly adhered to in using and disposing of any solvents.

Theatrical 35 mm release prints require considerably higher levels of lubrication to provide trouble-free performance during projection runs. Since the required amount of lubricant is excessive for overall application, it is applied to the perforated film edges only on the emulsion side. During windup, some of the lubricant transfers to the film edges on the support side. The edge-wax solution consists of 50 grams of paraffin wax dissolved into 1 litre of inhibited 1.1.1 Trichloroethane and is usually applied by a special edge-waxing machine. For more information, refer to the SMPTE Recommended Practice, RP151-1989, *Lubrication, Print.*

CHAPTER 6

Theatrical Projection

Today's multiplex in a suburban shopping plaza or mall can't match that great age of theatrical splendor, at least not in the architecture. Where today's cinemas can come up to the mark is in the quality of the offerings and the perfection with which they're projected. The big screen is still big. Dark still has its preconditioning power. The sound and color are better than ever. There is no reason why entering a modern theater should not be as great an experience today as it was many years ago.

The heart of the motion-picture theater, then and now, has always been the projection booth. It's the nerve center producing the thing for which the patrons have paid. The projectionists offer a magic show and hold in their skillful hands the quality of the presentation of a motion picture.

Maintenance

Manufacturing quality control and research and development of new materials, processes, and equipment stand at high levels in the industry that supplies the projection equipment. No piece of equipment can stand up to abuse over long periods nor to the less dramatic, but no less damaging, benign neglect that too often marks our approach to machines that we take for granted. No book like this can give a complete course in everything that needs to be known about sophisticated equipment. There are some pointers about its maintenance and operation that will contribute significantly toward high-quality presentations.

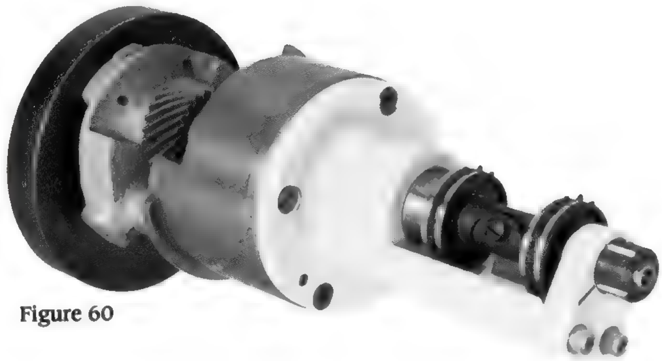


Figure 60

Major Maladjustments

When the show depends on the complex mechanical, electrical, electronic, chemical, and optical answers to tough technical questions, it can be threatened at scores of places along the line. And that's leaving out the other things that can go wrong in the human affairs that surround the technology of projecting a film.

The best guide through the intricacies of projection equipment is the manual that accompanies it. But let us emphasize (and maybe review) a few important points here.

Intermittent Movement and Sprockets—Adequate response to maintenance needs depends a lot on the ability to recognize worn or malfunctioning parts, to know the consequences of their defectiveness, and to carry out their correction. For theatrical motion-picture presentation, the heart of the projector is the intermittent movement (**Figure 60**).

This extremely durable mechanism imparts a precise and necessary intermittent motion to the film. It positions each frame with a maximum variation of about 0.0004 inch. So, when the screen image is 20 feet high, its vertical unsteadiness from the intermittent alone should be less than 0.2 inch.

Maintaining an intermittent movement is very important to the entire show. Let's consider the care of one part, the intermittent sprocket. How often should it be changed and why? Is the sprocket diameter worn down? Are the sprocket teeth worn flat? Could be, but you may find instead that a groove is worn into the leading edge of the sprocket tooth near the base. As more and more film is run through the projector, the groove deepens and causes the tooth to become hook shaped (**Figure 61**). Now, perforation damage begins, along with unacceptable screen-image unsteadiness and a noticeable increase in film noise level.

This type of sprocket-tooth wear is found almost exclusively on the intermittent sprocket. But physical abuse can cause damage to any sprocket. Metal tools hitting a tooth or a metal-pad roller that is out of alignment and

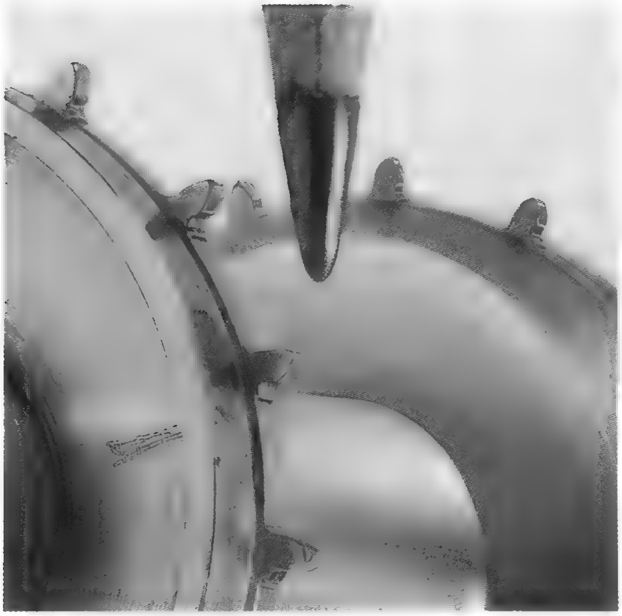


Figure 61

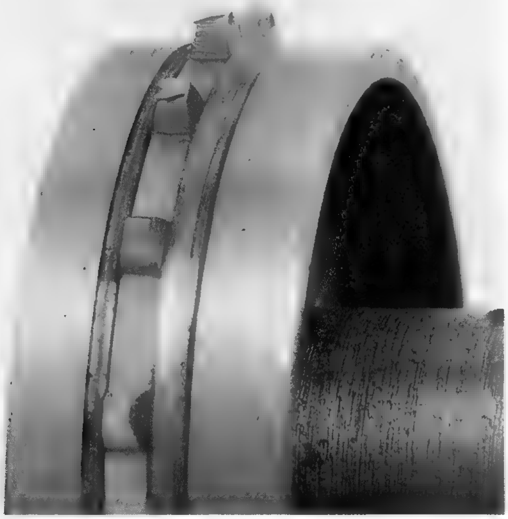


Figure 62

skiving the edge of the teeth are examples of such physical damage. Thus, when a sprocket is changed in time, needless damage is prevented to valuable film and it also helps to keep the projector in good condition—perhaps years longer than if it were not changed.

And there is more. A damaged tooth with a burr (**Figure 62**) can raise havoc with the perforations in a misaligned projector. The sharp edges of a tooth can score the perforation wall and start long cracks that can ruin an entire reel of film. During projection it's often difficult to hear the telltale noises that usually indicate sprocket-tooth damage. Whenever possible, you should check the threading by hand cranking and listen for a ticking sound as the film enters or leaves a sprocket. Such a sound signifies that the sprocket tooth is not engaging or disengaging smoothly on the perforation wall. If damage is found on the tooth, change the sprocket. If grooves are detected on the intermittent sprocket teeth but nothing else, reverse the sprocket and continue operating (the bottom of the teeth will now be used). We recommend the installation of a new sprocket as soon as possible. In 8 mm and 16 mm projectors, the claw pulldown mechanism is considerably more protected from accidental damage that could produce burrs. Wear can still cause a groove to be worn into the claw tines. You should replace the claw pulldown when such a groove is observed.

Be particularly observant for sprocket-related conditions, such as misalignment, that can cause film damage. A new sprocket can cause perforation damage just as a worn or damaged one if misalignment is severe enough. This type of problem is usually found between the film supply and feed sprocket or the holdback sprocket and film take-up unit, whether reels or platters are used. Make sure the reel spindles are not bent and that they are parallel to the sprocket shaft. If using either a platter system or outboard reels, be certain that the idler rollers on the projector are adjusted so that the film is perpendicular to the projector sprockets and that the sprocket teeth are evenly spaced in the perforation. This is best done while the film is being advanced by hand so that the position of the film over the sprockets can be closely observed while any required adjustments are made. Film can be stubborn. Adjustments made while the film is at rest do not take into consideration the film's natural tendency to seek its own path or the possible misalignment of other components. Misalignment is not generally a problem in 8 mm and 16 mm projectors since the film tension throughout the film path is much lower. Obvious mechanical-alignment irregularities should be corrected to prevent film damage.

Fire Rollers

For historic interest, we mention magazine-valve rollers, or fire rollers (**Figure 63**), as they are sometimes called. These rollers were designed for 35 mm projectors to prevent fire from reaching the magazines, an absolute necessity during the era when nitrate-base films were in wide use. With safety film, these rollers are no longer needed. They were always a potential for scratches. When 16 mm projectors were first introduced, Eastman Kodak Company declared that it would not manufacture amateur films on nitrate base because of the inherent danger of fire. As a result of this declaration, 16 mm projector manufacturers did not see the need for similar rollers on their equipment.

The projector gate can be another source of film damage. Hard deposits on the trap rails (**Figure 64**) can cause excessive tension and perforation damage. Remember, too, that this type of tension causes unnecessary wear of gate components and puts a greater strain on film perforations and the intermittent movement or other pulldown mechanisms.

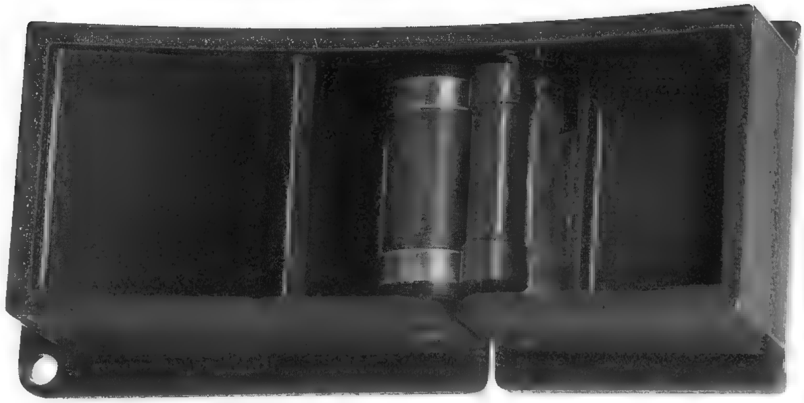


Figure 63

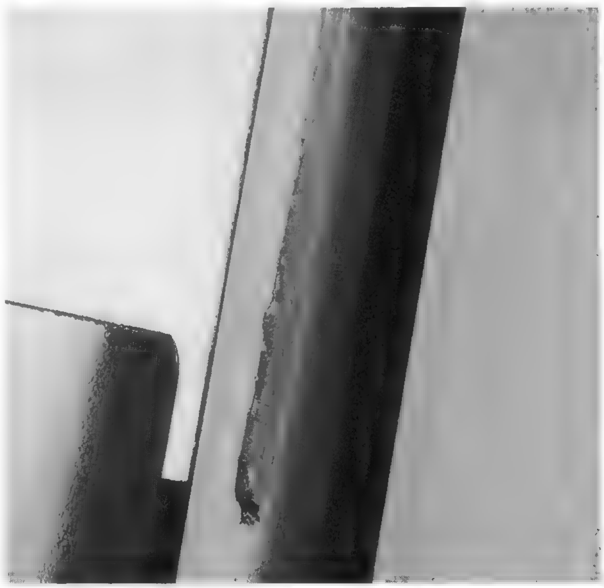


Figure 64

Reel/Hub Ratios

It's important to check the spindles of reel arms or magazines to make sure they rotate properly. Without some method of controlling reel tension, a maximum ratio of 3:1 between the reel diameter and the hub diameter is recommended if perforation damage is to be prevented, especially on projectors that use 16- or 24-tooth sprockets. Even at this ratio, perforation damage can occur if the tensions are not adjusted correctly. These requirements are met by the standard 2,000-foot reels. Extra-large reels with reel-hub ratios up to 6:1 seriously tax the ability of some projection systems to maintain desirable tensions on the film. If these conditions exist in your theater, the projector can be causing some perforation damage on all the prints that are run. If the equipment is new and designed to control film tension when using extra-large reels, be sure to check the system frequently. Perforation damage is more likely to occur as the tension approaches maximum; that is, when either the supply or take-up reel is nearly empty.

On start-up, be absolutely sure that there is no slack between the reels and the projector. Any time the holdback sprockets are heard *singing,* tension is probably excessive and can cause severe perforation strain and damage due to cinching. As mentioned earlier, a burred or worn sprocket tooth can cause the same sound. In either case, you need to investigate. Reel/hub ratios are less important in 8 mm and 16 mm. Since comparable diameter reels weigh less loaded with the film, the tensions required to achieve proper film control are also less. Be careful when using equipment that permits the use of the currently available large-capacity reels of 6,000 feet or more. For these large reels, as well as platter systems, it is wise to add polyester leader for start-ups.

Hot Lamps

Heat from the lamp can damage the film being projected, particularly with projectors that use carbon-arc (almost never used today) or xenon-arc lamps. The occurrence of such damage during theatrical projection appears to have decreased in proportion to the reduced use of black-and-white film, but the possibility is still there. Particularly in the *drive-in* where there is a strain to get as much light on the screen as possible. Black-and-white film damages from heat faster than color because the image is made up of metallic silver that absorbs energy faster than the color dyes. A misadjusted lamp that causes a center *hot spot* can create a separation between the emulsion and the base. The thin emulsion becomes isolated and can't transfer the heat to the base, so it chars. A blistered print is useless and must be junked.

Note: Blistering is practically nonexistent in portable projectors using tungsten lamps, unless the film comes to a stop in the aperture.

Color films can withstand considerably more heat than black-and-white films, but it is still possible to *frame-line* blister 35 mm color prints where the film comes into contact with the top or bottom edge of the extremely hot aperture plate. Normally, this should not happen. But some aperture plates are *custom-filed* to fit a variety of situations. During this customizing process, the aperture edge can have leftover burrs that extend into the film-plane area. Furthermore, when filing out the aperture, it's possible to bend the plate in the direction towards the film. This type of blistering may not be noticed during normal projection because it usually occurs only on the top or bottom edge of the projected frame and thus ends up on the black screen-masking area. A change in framing will quickly show a small horizontal line of blisters near the top or bottom of the screen image. And, if the picture is cropped smaller than normal for the particular format, the next projectionist will not be able to frame the blisters out if the correct, but larger, aperture plate is used.

With xenon short-arc lamps whose optical characteristics are considerably different from traditional carbon-arc equipment, if the lamps are correctly installed and if safety measures and operating procedures are not circumvented, it is not possible to blister color print films in the picture area.

Image Luminance

Persistent flicker, particularly on light scenes—such as sky, snow, beaches, or deserts—may indicate excessive screen luminance. It becomes more distracting nearer the screen. On the other hand, if medium or dark scenes fail to show detail, the screen luminance is too low. Theatrical prints are made to be viewed at a recommended screen luminance of 16 ± 2 footlamberts as stated in the ANSI/SMPTE Standard PH196M-1986 and SMPTE Recommended Practice RP-98-1990. Any significant departure from these values will not provide the best screen-image quality.

Projection of 8 mm and 16 mm films doesn't usually require the high energy levels necessary for theatrical projection, but care must still be taken to avoid projection slowdowns and stops while the projection lamp is on. If a shutter blade doesn't interrupt the light beam when the projector is stopped, the film will blister in the aperture. Projection of 16 mm, utilizing xenon-arc lamphouses, requires the same precautions stated for theatrical projection. Remember to illuminate a 16 mm screen image to the same level as an equally sized 35 mm screen image because it requires about four times more light-flux intensity on the film.

The Light

If the screen-luminance level is measured with a suitable light meter and the values are out of range, adjust the light level to conform with the recommended values. Excessive luminance is usually easy to remedy. Simply adjust the lamphouse to a lower current for xenon arc or use a smaller incandescent bulb. With xenon lamps, light output can vary considerably without changing the color quality of the light.

There are a number of things that can cause insufficient screen brightness, but perhaps you should start with the lamphouse. Is the lamp burning at the recommended voltage and current? Is the light source positioned at the proper distance from the mirror? Is the lamphouse the correct distance from the projector? Sometimes, when viewing a bare screen, you might move the lamphouse to even the light on the screen. If the lamphouse is moved too much, the cone of light will be larger than necessary and waste a good portion of the light around the aperture (**Figure 65**).

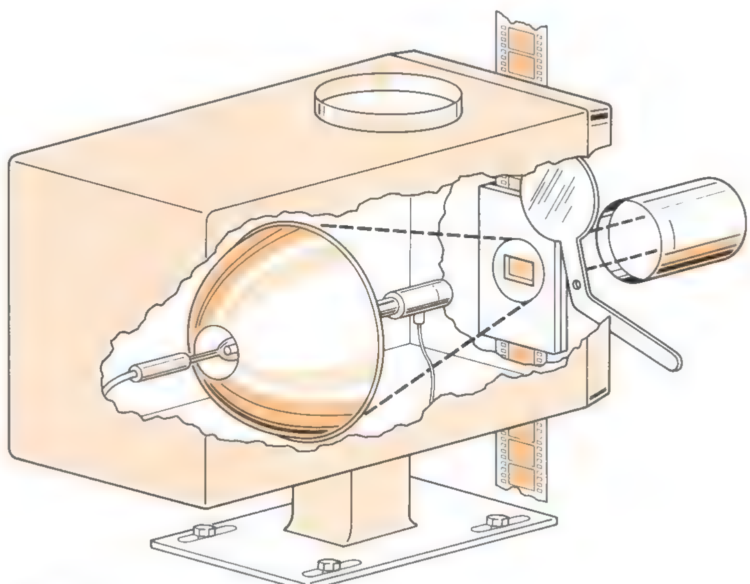


Figure 65

Incandescent lamps are generally prefocused and cannot be adjusted further. Did you check the mirror, the projection lens, and the port glass? If these components are clean and properly aligned, and screen luminance is still too low, then you should probably increase the lamp output if it's within the ability of the equipment. After the increase is made, you should understand why the lamp output was insufficient (for example, a dirty screen, clouded or dirty optics, or mirrors coated with dust and dirt).

Screens can become very dirty. The best standard of comparison is to keep a piece of the original screen material (stored in a light-tight container when first purchased). If the original is not available, make a comparison with a sheet of plain white bond paper. Sometimes you can remove, by vacuuming or with a very soft cloth or a screen brush, dust and dirt accumulations, but be careful not to let dirt particles scratch the delicate reflective coating. Check the manual for cleaning suggestions for the screen or contact a theater-supply dealer.

Stray Light

Even with the proper screen brightness, excessive stray light coming from unshielded lights, exits, concession stands, backstage lights, etc., can deteriorate picture quality by reducing the apparent contrast of the projected picture.

Measurement of stray light requires sensitive meters and special techniques, but you can get some idea of how the theater rates by standing on the stage in front of the screen and facing the projection room. With the house lights down, but without the projector running, distracting stray-light sources can be spotted easily, after giving the eyes a chance to adjust. It is important at this point to differentiate between a small bright source of light, such as an exit sign or bare bulb, and an overall glow from the ceiling or walls.

Figure 66a

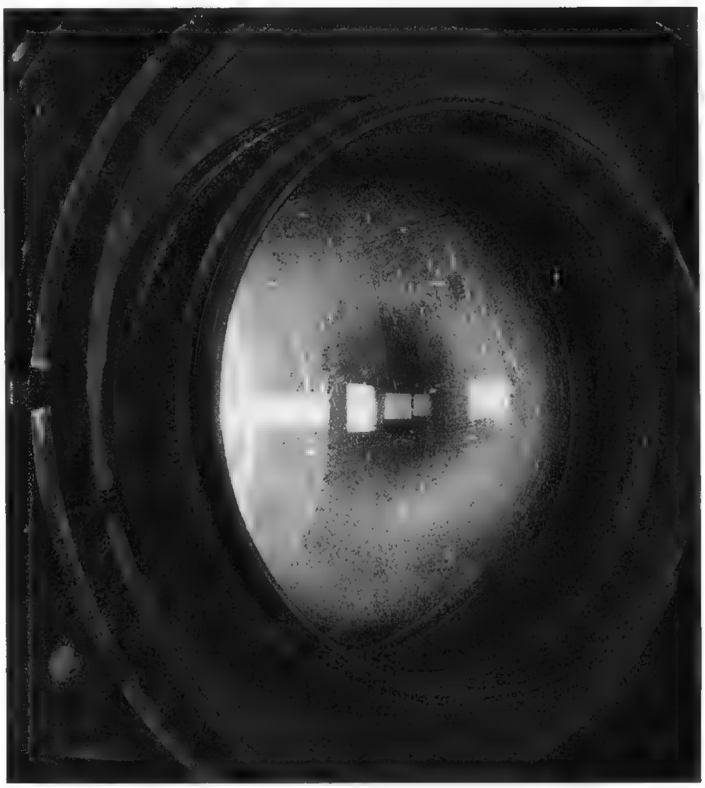


Figure 66b

Either source could cause distracting stray light. You can determine which one it is by conducting a simple test on each source independently and then together. While standing on the stage in front of the screen facing the projection room, try to read the white pages of a standard telephone directory. If you can read them, even slightly, the stray-light level is probably too high. If you can't read them, the stray-light level in your theater is probably close to the recommended level of less than 0.5 percent of the recommended center-screen brightness. Once you determine the source of the stray light, remedial measures can begin. For the best-quality screen image, the stray light should not exceed the recommended level. Remember that release prints are manufactured to provide a satisfactory screen image only under luminance and stray-light conditions specified in published standards.

Lenses and Mirrors

Dirty or clouded projection lenses and other optical components are among the conditions that adversely affect screen-image luminance and contrast. You can carefully clean the outer surfaces of a projection lens but not the inner surface unless you disassemble the lens. Actually, the incidence of internal clouding on modern projection lenses is quite low. Older lenses, with less permanent seals, are more likely to have become cloudy from years of use. During projection, glance carefully into the lens from a point just outside of the main projection beam (**Figure 66a & Figure 66b**). This will allow you to see into the lens barrel without difficulty. If the lens surface appears brightly illuminated, there is probably some deposit on that surface.

Caution: Do not look directly into the lens because it could cause serious eye damage. Cleaning inner-lens surfaces should be left to qualified repair shops, because special tools and alignment procedures are needed to properly dismantle and reassemble a projection lens.

Generally, the mirrors in the lamphouse get quite dirty. There probably is little reason to open a xenon-arc lamphouse, except to change the lamp. During the extended period when the lamphouse is unopened, air currents from ventilation, along with electrostatic charges produced by the current flow, can cause a considerable amount of dust and dirt to deposit on the mirrors. On occasion (perhaps once a month), you should open the lamphouse and check for such deposits—after you have first observed the posted xenon-lamp safety measures regarding face masks and lamp covers. When you check the equipment in the projection room, remember to check the port glass. If the glass is clean, you shouldn't see a frame outline on the glass surface as the projection beam passes through. If you do see a strong image on the glass, it's due to dust, dirt, smoking, or abrasion from repeated cleaning by improper means.

If all of the projection equipment in the auditorium and projection room checks out satisfactorily and screen luminance is still on the low side, you may need to consider a new screen or a larger lamphouse. Since both of these choices involve considerable expense, you should consult the theater-supply dealer for suggestions.

Projection Practices and Techniques

Regardless of the type of 35 mm projection equipment you use, the film path through the projector will be essentially the same. In a conventional projector, the film is threaded from top to bottom through many curves and turns—where if misthreaded, damage can occur. Form proper loops, check for worn rollers, and seat the film properly on the sprockets and in the gate.

Carelessness—Film Damage

A film improperly seated over a sprocket, a pad roller that creases the film edge, and excess oil in the film path are some of the most common causes of film damage, abrasion, and dirt in the projector. After completing thread-up, reexamine the entire film path and advance the film by hand to check it out. Has all the slack been taken out of the system? Are tension devices correctly adjusted for the large reels? Is the film properly seated on all the idler rollers in a platter system? A *singing* sprocket signifies excessive tension somewhere in the film path. Continued projection under these conditions results in perforation wear and premature perforation breakdown. Polyester films take wear better, but continued deformation of perforations can eventually lead to breakdown of any material and an unsteady screen image.

Focus

Film wound emulsion-out on small cores has built-in strains that decrease as the diameter of the reel increases. During the normal projection of 35 mm theatrical film on 2,000-foot reels, the focus position will shift from one end of the reel to the other. This focus shift depends somewhat on the amount of heat energy that is applied to the film. As a result, sharp focus at the start of a reel becomes increasingly soft as the end of the reel approaches. Check the focus frequently if you use cored rolls. Even though a platter system holds the focus very well, it still should be checked at the start of each showing. Film stored wound emulsion-in will exhibit almost no focus shift. Film kept wound on reels with large-diameter hubs has less strain-related focus drift.

In some theaters, adequate focus is likely to be a compromise among a combination of factors, such as large projection angles, curved screens, and projection axes that are not perpendicular to the screen in both the vertical and horizontal planes. Since the center of the screen is the focal point of most story action, the best focus is usually adjusted for the screen center.

Sound

During threading, the length of the loop between the intermittent sprocket and the sound sprocket is critical. A 21-frame thread-up separation (**Figure 67**) brings corresponding picture and sound to the screen and speakers simultaneously.

This is obviously the preferred thread-up where the speaker is close to the viewer. Since sound travels at 1100 feet (335 metres) per second, a 20-frame thread-up separation produces this synchronous effect at about 45 feet (13.7 metres) from the screen. A compromise thread-up separation is determined by the physical size of the theater. During the projection of a magnetic-track print, you must give the same attention to lip sync. With a magnetic-sound head, the frame separation is 28 frames (**Figure 68**), not 21, and because the sound lags behind the corresponding picture frame, a one-frame increase for every 45 feet (13.7 metres) from the screen is needed.

A typical optical sound track, or tracks (**Figure 69a**), on most release prints are recorded, printed, and processed to provide equal volume levels when reproduced. Special sound effects and unusual requirements may be effected by the exact sync, but a considerate projectionist should step out into the auditorium from time to time and judge the sound for volume level and intelligibility. The correct volume level for a full house will differ from a nearly empty house. To *ride the gain* would not necessarily enhance the presentation, and shouldn't be done unless a very good compromise is reached.

Optical-Digital Sound

A new superior-quality motion-picture sound was introduced in 1990. The concept was invented by Eastman Kodak Company and adapted for the theater by Optical Radiation Corporation, Azusa CA.

Optical-digital sound (**Figure 69b**) provides six discrete channels of crystal-clear audio, the quality of a compact disc, which surrounds the audience with dialogue, effects, and music. Five of the channels are full-band that are capable of reproducing the full dynamic and frequency range that the human ear is capable of discerning, from the softest to the loudest, and from the deepest bass to the highest treble. A sixth sub-offer channel carries the deepest bass tones. Optical-digital sound is a dye track, not silver.

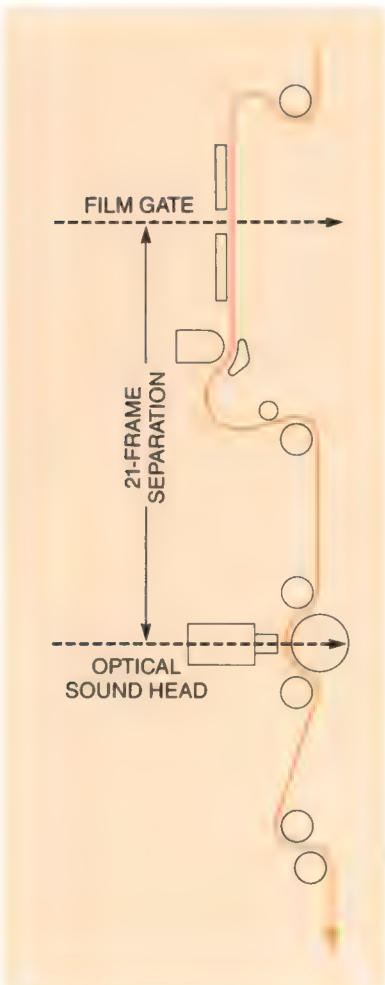


Figure 67

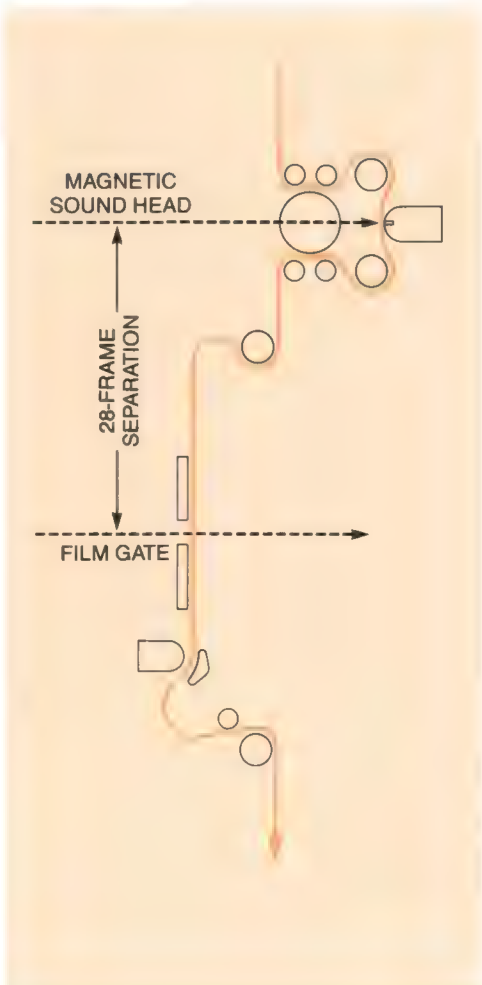


Figure 68

Figure 69a

Figure 69b

Screen Luminance

Release prints are exposed, printed, and processed to be viewed at a screen luminance of 16 ± 2 footlamberts, measured with the projector running but without film in the gate. Any significant change from this level downgrades the quality of the screen image and, in the case of poor luminance, the image may be difficult to follow. The average theater owner or manager isn't likely to purchase equipment to check screen-luminance values but a theater chain might. In any case, you can arrange to have the screen luminance measured and have corrections made, if necessary. It could make a real improvement in audience satisfaction.

Rewinding and Handling

With reel systems, it's also important to review rewinding procedures to avoid potential film damage. Do not store leaders and trailers on a rewind bench or floor. When winding at any speed, but particularly at high speed under low-humidity conditions, you can generate static electricity charges that will act as a magnet to draw loose dirt from the bench. Since the static charge persists, the dirt particles migrate into the reel and eventually cause objectionable screen blemishes.

Good Judgment

The subjects discussed under "Projection Practices and Techniques" are major factors in providing a realistic and enjoyable screen image that doesn't detract from the total involvement of the audience. Lack of good judgment and practice in any one of these areas often causes substandard screen presentations and will adversely affect box-office receipts. Top-quality projection and sound in the theater will go a long way in making sure that viewers will want to come back again and again.

The "Projection Practices and Techniques" section of this book gives a good insight of film-handling problems. You can get additional information from KODAK Publication No. H-50, *The REEL PEOPLE Collection.*

Continuous Film-Cleaning System

Particle Transfer Rollers (PTR) have proven highly effective as a cleaning unit installed on theatrical movie projectors. They can be mounted as a unit (**Figure 70**) on the projector to continuously clean the film during the normal projection period and require only periodic cleaning with a damp sponge and water. If you have questions or want to order the PTR, see page 59 for the address and telephone number.

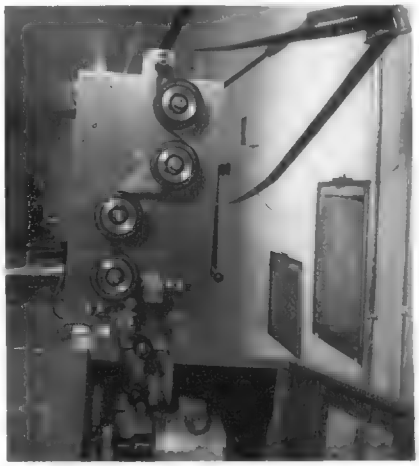


Figure 70

CHAPTER 7

Rejuvenation/Film Treatment

What Is "Rejuvenation?"

When a film doesn't warrant the expense of being remade, but is still wanted, rejuvenation may be the answer.

There are facilities that specialize in rejuvenating films in just this kind of situation. Rejuvenation means giving a temporary new lease on life to a much-used (or abused) film by inspecting and cleaning it, testing and repairing its damages, often applying protective coatings, splicing in replacement sections, removing or tempering scratches, and moisture conditioning it. Done well, each of these techniques involves some special skill. Doing all of them together so that they have a cumulative effect constitutes a professional specialization.

Although most rejuvenation techniques are proprietary, the basic concepts are known. To begin with, you can't improve a film that has been abraded on the emulsion side if image information has been physically removed showing clear grooves. Once a deep emulsion scratch is made, no film treatment can refill the gap. Fine emulsion scratches can be subdued and sometimes eliminated by applying a lacquer or similar coating or by simply reprocessing (except in a black-and-white reversal process). You can treat base scratches in several ways, one way is by a controlled application of an active solvent that partially softens the scratch edges, making them less visible during projection. Other methods include a hot wheel that softens the support enough so that the edges of the scratch will round out and press in as the film goes over a flat-surface wheel while under tension. It is conceivable that a combination of all three—solvent, hot wheel, and pressing—can be used.

Caution: Great care is necessary when these techniques are employed because permanent physical deformation, including change in pitch dimensions with hot-wheel treatment of the base, is possible.

Film that is physically distorted or brittle can sometimes be made usable, but the results of the treatment are only temporary. In some cases, laboratories may make a master or duplicate negative for protection in the course of the treatment. All films reaching a *questionable* stage should be considered for duplication if the image is to be saved.

Other physical damage, such as broken or missing perforations, can also be repaired if it isn't extensive and can survive subsequent projection. If a damaged print does not warrant the expense of being reprinted, the choice of rejuvenation is an option, but comparative costs should be requested.

Restoration/Duplication

Don't attempt to examine an old film for restoration unless you are thoroughly familiar with its physical characteristics and know how to unroll it. Chances are likely that the film base is nitrate and probably extremely brittle and shrunken. Projection of the film would severely damage or totally destroy it. If the film is sticky, or if the image is partially missing, remove it from current facilities to a cool storage area that is fireproof or isolated from other areas. Even in an advanced stage of deterioration, many films can be restored by the experts if you are willing to bear the expense.

Where to Find Services

Film rejuvenation or restoration isn't a job for the amateur and isn't always needed by everyone. If there is a film that seems worth restoring and you are not sure what to do with it, contact the nearest film archive. A comprehensive list of film archives worldwide can be obtained by writing to: FIAF Secretariat, rue Franz Merjay 190, 1180 Brussels, Belgium. Or you may choose one of the companies listed below. Choose a company that meets the standards for effectiveness, speed, and cost.

The following companies are listed for the convenience of our customers. This does not constitute a recommendation or endorsement by Eastman Kodak Company.

Accutreat Films Inc.
630 Ninth Avenue
New York, NY 10036
(212) 247-3415

AFD/Photogard/Durafilm
Film Coating Laboratory
1015 North Cahuenga Blvd.
Hollywood, CA 90038
(213)469-8141

Benke Filmtex
10554 West Victory Blvd
North Hollywood, CA 91606
(818) 846-1609

Cinema Arts Inc.
P.O. Box 70
South Sterling, PA 18460
(717) 676-4145

Cine-Tech
920 Allen Avenue
Glendale, CA 91201
(818) 242-2181

Filmtreat International Corp.
42–24 Orchard Street
Long Island City, NY 11101
(718) 784-4040

FPC Inc.
6677 Santa Monica Blvd.
Hollywood, CA 90038
(213) 465-0609

HFC Rejuvenation
826 Seward
Hollywood, CA 90038
(213) 462-1971

Restoration House
Film Group Inc.
P.O. Box 298
Belleville, ON K8N 5A2
Canada (613) 966-4076

WRS Film Labs
1000 Napor Blvd.
Pittsburgh, PA 15205
(412) 937-7700

YCM Labs
2312 West Burbank Blvd.
Burbank, CA 91506
(818) 843-5300

Corrective Reproductions/ Color Films

Two methods available for making corrective reproductions of faded color motion-picture prints are described in detail in an article by C. Bradley Hunt titled *Corrective Reproduction of Faded Color Motion Picture Prints* in the SMPTE Journal for July 1981, pages 591–596. In both methods, a new internegative is made by printing a contrast-correcting color mask with the faded print. An example of a faded-color reproduction is shown below (see "Dye Fading Considerations" for more information).

Chemical restoration and the printing of black-and-white separations (masks) have been used for some time. Chemical restoration selectively reduces or intensifies film dyes. Disadvantages of this method include possible total destruction of the dyes or film, uncertain repetition of results, and limited color-correction capabilities.

Black-and-white separation printing offers better repetition of results and greater safety for the original film. It does involve costly printing of three black-and-white color separations or masks. Don't mistake this method for the making of black-and-white separation positives from a color negative—still the preferred technique to preserve films for extended-life storage.

Dye Fading Considerations

The degree and type of dye fading that occurs in a color print during dark storage depend on many factors. One noteworthy characteristic of dye fading that normally occurs with dark storage is that the degree of dye fading is proportional to the amount of dye present in the film. This means that in a positive print, more dye loss will occur in high-density shadows than in low-density highlights. **Figure 71,** Log Exposure (a) depicts possible cyan-dye fading and a contrast loss; Log Exposure (b) shows the color balance correction; and Log Exposure (c) shows the color contrast correction, bringing both color and contrast to a restored (close to the original) level (c).

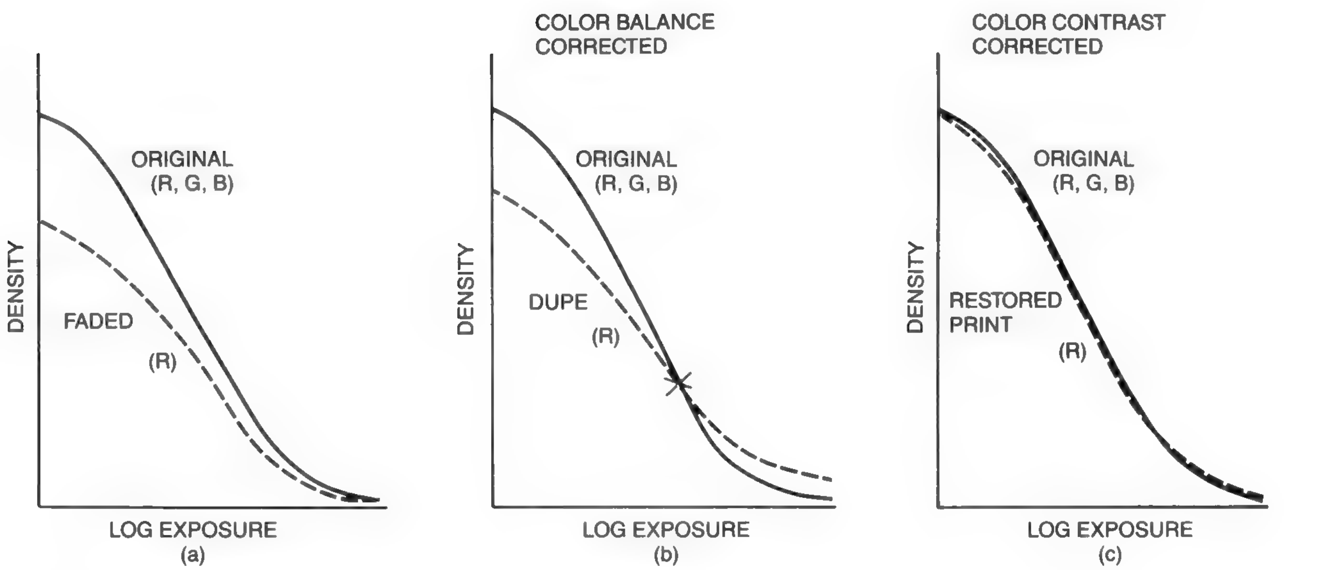


Figure 71
Sensitometric D-Log E print-through curves representing cyan dye fading and its correction:
(a) red density curve for a faded print (dashed line) compared to the original curve;
(b) red density curve for a midscale color-balance-corrected duplicate;
(c) red density curve for a contrast-corrected restored print.

CHAPTER 8

Appendices

Appendix A—ESTAR Base Motion Picture Film Materials

Film base must be flexible but tough, able to bind photographically sensitive materials over clear base, while being thin enough to keep cameras, projectors, and reels at manageable sizes. Cellulose-nitrate films and the current safety cellulose-triacetate base have fulfilled these functions with various advantages and disadvantages. Polyester films, such as KODAK ESTAR Base, also have pluses and minuses.

General

ESTAR Base has a different chemical structure and physical properties than cellulose-triacetate base. For equal thicknesses, ESTAR Base has greater strength, stiffness, and tear resistance than triacetate. These improved properties allow 35 mm motion-picture films on ESTAR Base to be approximately 15-percent thinner than on acetate films. Some 16 mm and super 8 films have been manufactured on ESTAR Base which is approximately 30-percent thinner, but these films require extra care in handling.

ESTAR Base is less susceptible to moisture, which is a contributing factor to its better dimensional stability. It has no residual solvents, which is one reason for its very low long-time shrinkage. Other differences show up in winding, curl, and splicing behavior.

ESTAR Base Film's sturdiness often gives the less experienced filmhandler another chance. Its thinness offers economy of size along with sturdiness for film cassettes. Finally, its moisture resistance and dimensional stability seem to promise much to the archivist or curator. But no film can be all films to all filmhandlers, so a realistic assessment of its qualities and some of its handling characteristics follow.

Curl and Winding Effects

Curl and winding effects are closely entwined in motion-picture-film behavior. Curl is defined as the departure from flatness. At low relative humidities, the emulsion shrinks more than the base. This tends to cause the film to curl toward the emulsion side. As the relative humidity increases, this contractive force decreases and the inherent curl of the base becomes predominant.

When film is wound in roll form, the inner surface is compressed and the outer stretched. With time, the film undergoes *plastic flow* and assumes this configuration. When the roll is loosened, the film has lengthwise curl which is called *core-set*. When such a strip is unrolled on a flat surface, the lengthwise curl is transformed into widthwise curl. The level of this curl is also affected by the relative humidity as explained above. In motion-picture films, the core-set effects are predominant. ESTAR Base Films require a longer time to acquire core-set than acetate films, but they also retain it longer.

Stiffness

The stiffness or rigidity of a film depends on both the thickness and base material. ESTAR Base Films are stiffer than acetate of comparable thickness, consequently they can be somewhat thinner and still perform satisfactorily. Insufficient stiffness may be a controlling factor in how thin a film with ESTAR Base can be made and still survive its twists and turns through film-handling equipment. Film performance in such equipment depends very much on thickness, and a thin film can become unmanageable if overpowered by equipment.

Splicing

ESTAR Base Film ends can be joined to each other and to other types of film base by tape splices. Organic solvents are the cements used to splice cellulose-triacetate-base films. But these solvents do not work on polyesters; therefore, dielectric heating, ultrasonic energy, radiant (hot-wire) or energy-splicing tapes must be used on ESTAR Base Film but not in combination with other film bases. These thermal methods leave the final molecular orientation of the polyester sufficiently unchanged so that the film keeps its sturdy physical properties.

But what if we have triacetate- and polyester-base films together on a reel? Then we must use pressure-sensitive splicing tape. Over the years, this method has gained popularity. These very flexible and highly adhesive splicing-tape tabs are not likely to come apart or break during projection.

Film Positioning

Most cameras, projectors, and rewind equipment are probably built to accommodate thicker acetate films. The clearances and pressures suitable for the thicker films are not always the best for thin films. The thinner film has a tendency to wander more within the extra dimensions of the equipment. Firm but gentle film guides, gates, sprockets, and other mechanical handling apparatus are required with thinner films.

Projection Thermal Effects

During projection, the heat energy incident to the film in the aperture causes the emulsion to expand. This is normal in all projection formats but can be troublesome in large theatrical situations.

Depending on the amount of heat, thickness of the film base, and the size of the film image, the film has been observed to move as much as 0.045 inch from the flat image plane in the projector. This movement can cause a temporary but unpredictable movement of the film that affects focus of the screen image. The problem is mostly apparent during the projection of black-and-white films that contain a metallic silver image which absorbs all of the heat energy. The same films used on smaller formats generally do not receive the same amount of incident energy. Also, because the image and film size are much smaller, the film appears actually stiffer and can resist thermal effects more readily.

Resistance to Scratching

ESTAR Base Film may be somewhat resistant to scratching but only on its base side. The emulsion side is equally vulnerable to scratches, whatever the base.

ESTAR Base is a useful film support, but its sturdiness is no excuse for less-than-careful film handling and storage. Good practices for controlling abrasion, providing adequate lubrication, maintaining cleanliness, and making sure film positioning and guiding mechanisms perform adequately are just as important for ESTAR Base Materials as they are for triacetate-base films.

Peculiarities of Thin Film

Here are some peculiarities of thin film that still challenge film and equipment manufacturers and that may be encountered in use:

- Tendency to climb reel flanges
- Possible skewing or pulling into recessed rollers
- Distortion of perforations by sprocket and pulldown-claw mechanisms
- Unpredictable behavior when pushed into self-threading paths
- Bending and deforming caused by guiding and positioning forces along the film path
- Vibration of the perforated edge by the pulldown claw
- Increased screen-image problems due to thermal effects

Films with the physical characteristics of polyesters, such as ESTAR Base, can minimize a number of film-handling problems. But polyester-base film has its limitations and must be treated with understanding and respect for both its superior characteristics and its limitations.

Appendix B—Laboratory Tests for Identifying Acetate- and Nitrate-Base Films

Motion-picture films may sometimes be difficult or impossible to identify directly as nitrate or acetate, so a simple test is needed and one of the following may be used.

Burning Test

A test for a nitrate or a safety film can be made safely if you take certain precautions. Cut a small sample, about one inch, from the film and take it outdoors or into another room where no film or other hazardous material is present. If a long piece of film is ignited and it turns out to be nitrate, a serious burn or a bad fire may result. The burning test must be made in a carefully prescribed manner or an inexperienced person may still confuse nitrate and safety film, particularly since only a small sample can be burned safely.

Sample. Cut a piece of film approximately 16 mm wide and 35 mm long. Bend the film lengthwise and crease it sufficiently so, when it's released, it will stand upright.

Procedure. Stand the film sample (with the crease vertical) on a flat surface such as a glass plate or a concrete floor. This should be done at a safe distance from all film stocks. With a match flame, ignite one of the top corners of the film. Anyone unfamiliar with the burning of safety film and nitrate photographic films should first conduct this test on samples of both types of film, the identities of which are known.

Interpretation. If the film ignites easily, burns downward rapidly and vigorously with a bright yellow flame, and is completely consumed in less than 15 seconds, it probably contains dangerous quantities of cellulose nitrate and probably will not pass the standard tests for safety film. If the film sample ignites with difficulty and burns only partially, or if it burns completely in a time not under 15 seconds, compliance with the standard tests may be considered assured and the film classified as safety film. If the results of the field tests are doubtful, the laboratory tests specified in the following standard should be conducted.

Chemical Test

There is a standard chemical test known as the Diphenylamine Test for the nitrate-molecular group which is present in cellulose-nitrate-base film. The details of the test are not given here because it should not be used for testing film by anyone other than a trained analyst. It is so sensitive that it will give a positive reaction on safety film containing a mere trace of cellulose nitrate in the sublayer (and acetate does have a trace) unless the sub is first removed.

Appendix C—International Standards ISO 4331 and 4332*

ISO 4331 Photography—*Processed Photographic Black-and-White Film for Archival Records—Silver-Gelatin Type on Cellulose Ester Base—Specifications*

ISO 4332 Photography—*Processed Photographic Black-and-White Film for Archival Records—Silver-Gelatin Type on Polyester (Ethylene Terephthalate) Base—Specifications*

Forward

ISO (The International Organization for Standardization) is a worldwide federation of national standards institutes (ISO Member Bodies). The work of developing International Standards is carried out through ISO Technical Committees. Every Member Body interested in a subject for which a Technical Committee has been set up has the right to be represented on the Committee. International organizations, governmental and nongovernmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standards ISO 4331 and ISO 4332 were drawn up by the Technical Committee ISO/TC 42, Photography, and were circulated to the Member Bodies.

It has been approved by the Member Bodies of the following countries: Australia, Austria, Belgium, Canada, France, Germany, Italy, Japan, Mexico, Poland, Romania, South Africa, Republic of Spain, Turkey, United Kingdom, U.S.A., U.S.S.R., and Yugoslavia.

No Member Body expressed disapproval of the document.

Introduction

Since 1930, great advances have been made in the use of photographic films for the preservation of records. The preservation of film records by governments, banks, insurance companies, industry and other enterprises has been stimulated by a recognition of the economics in storage space, organization, accessibility, and ease of reproduction that results from the use of film records.

During the early development period of the art of copying documents, 35 mm nitrate motion-picture film was sometimes used. This material is highly flammable and deteriorates rapidly under unfavorable storage conditions. Nitrate film is not acceptable for any archival record use. The manufacture of nitrate film stopped after 1949 in the United States and was discontinued in most other countries in the 1950's.

For many years, the only films suitable for archival storage were made on some type of cellulose-ester base. Various synthetic polymer-base films have since appeared. The useful life of cellulose-ester-type material extends back only to about 1908. Experience with the film during that time and the results of accelerated-aging tests and other studies predict that the material is capable of enduring as long as rag paper under specified storage conditions.

The International Standard is intended to eliminate possible hazards to permanence attributable to the chemical or physical characteristics of the processed film. It is the responsibility of the film manufacturer and/or the film processor to identify some of those characteristics. Specifying the chemical and physical characteristics of the material does not, by itself, ensure satisfactory archival behavior. It is essential to provide proper storage temperature and humidity and protection from the hazards of fire, water, fungus and certain atmospheric pollutants.

*A complete copy of International Standards ISO 4331 and ISO 4332 can be obtained from the American National Standards Institute (ANSI) or the International Organization for Standardization (ISO). Refer to the addresses listed on page 18. In 1990, the ISO/TC 42 Committee met to draft a revision to the above standards. The Draft International Standard is ISO/DIS 10602.

Appendix D—Method of Desiccating Film

Processed 35 mm film and either raw or processed 16 mm film may be desiccated (dried) when necessary by means of activated silica gel. The desiccation of raw 35 mm or wider film is not recommended. Anhydrous-calcium chloride, sometimes used as a desiccant, is not recommended for drying film because it liquifies when moist and is messy and corrosive.

Silica gel may be obtained from W.R. Grace and Company, Davison Chemical Division, P.O. Box 2117, Baltimore, MD 21203, either in bulk or in small perforated aluminum containers called "Silica Gel Air-Dryers." These come in two sizes, one containing about 17 grams (⅔ oz) and the other about 38 grams (1⅓ oz) of silica gel and a color indicator which turns from blue to pink when the silica gel needs reactivating. Silica gel is reactivated by heating in a vented oven at approximately 300°F for about 3 hours, or until the deep blue color of the indicator is restored. Bulk silica gel should be spread out in a tray not over an inch deep for reactivation. After reactivation, the silica gel must be sealed immediately in a vapor-tight can or jar for storage until needed. It may be used and reactivated over and over again.

Quantity of Silica Gel Required

The first consideration in desiccating film is to estimate the amount of silica gel required. The use of excess silica gel should be avoided in the case of raw film because overdrying increases the chance of static marking. The table (**Figure 72**) gives the recommended amounts of silica gel for processed 35 mm films. Use one-half as much silica gel for processed 16 mm films. Polyester (ESTAR Base) films need only two-thirds as much silica gel as acetate-base films.

Amount of Activated Silica Gel Required to Dry Film from One Relative Humidity to Another

Relative Humidity ➡	***30***	***40***	***50***	***60***	***70***	***80***	***90***
Final Relative Humidity (%)	**Ounces of Silica Gel per 1000 feet of 35 mm film**						
20	3.4	6.8	11	15	22	33	49
30	—	2.2	4.7	7.4	12	19	29
40	—	—	1.8	3.8	7.1	12	19
50	—	—	—	1.6	4.2	7.8	14
60	—	—	—	—	2.2	5.2	10

Figure 72

Procedure. Film to be desiccated should be removed from its container and placed in a larger can, along with the correct amount of activated silica gel, and sealed. Both surfaces of the film roll should be exposed to the drying action of the silica gel. If bulk silica gel is used, it should be separated from the film by a piece of thin muslin to prevent dusting. Where large rolls or several rolls of film are to be desiccated, a special air-tight metal box should be constructed. Shelves may be made of wire screen and placed about 2 inches apart so that rolls of film may be alternated with layers of silica gel. The film should be left in the desiccating chamber for the times indicated below (**Figure 73**).

Film Rolls	**Time Required for Desiccation in Weeks**	
	16 mm	**35 mm**
Flanged camera spools (100 feet)	2	4
On cores	1	2

Figure 73

In the case of raw film, processing should be arranged as soon as possible regardless of other factors. If time can be saved, the film may be shipped to the processing laboratory with the silica gel still in the container.* If this cannot be done, or in the case of processed film when desiccation has been completed, the film should be removed from the chamber and resealed with fresh tape in its individual container. The silica gel must then be reactivated before using again. More detailed information of film desiccation is given in the product manufacturer's literature.

*Provisions must be taken to keep the silica-gel particles from coming in contact with the film.

Filmhandlers' Checklist

Laboratory

- Maintain *white room* environment.
- Condition films adequately from deep-freeze keeping before using.
- Handle film by edges only, preferably while wearing clean, lintless gloves.
- Check that film is evenly wound with sufficient tension to prevent cinching, protruding edges, and dishing of the roll.
- Check camera originals for edge nicks before processing.
- Clean printer gate and check film path carefully before operating to prevent abrasion.
- Check all splices on raw stock prior to processing.
- Check all inspection equipment—projectors, viewers, lubricating equipment, etc.—to prevent abrasion and damage of new prints.
- Use only new or undamaged reels for prints to be shipped out on reels.
- Don't allow film to touch floor or bench top during inspection or winding procedures.
- Maintain log of all customer-submitted work.

Distributor—Library—Archives—Institution

- Keep area, bench tops, and equipment clean.
- Handle prints during rewinding by holding edges only. Clean gloves recommended.
- Check and remake all poor splices.
- Remove non-recommended tape reinforcements.
- Wind film evenly to prevent isolated film convolutions that are prone to damage.
- Check leaders and trailers to see that they match the reel number and title.
- Clean dirty and oily prints.
- Use only undamaged reels for storing prints.
- Tape film ends to prevent loose rolls and dirt migration into roll.
- Inspect stored film reels periodically, particularly if nitrate film is present (archival storage).
- Maintain recommended temperature/humidity conditions in storage areas as specified.
- Don't allow film to touch floor or bench top during inspection or winding procedures.

Theater Projection

- Keep area, bench tops, and equipment clean.
- Check print for poor and misaligned splices and other damage.
- Use tape splices to conserve film.
- Preserve and identify leaders and trailers removed during the makeup procedure.
- Replace leaders and trailers on proper reels prior to shipment.
- Check with distributor for replacement footage before removing damaged film from the reel.
- Check projector threading, roller alignment on platters, and tension adjustments on large reels.
- Maintain enough tension during winding to produce a smooth, tight reel and prevent cinching abrasion.
- Don't allow film to touch floor or bench top during inspection or winding procedures.
- Investigate the use of particle transfer rollers to maximize the *new print look.*

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American Cinematographer

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BKSTS Journal

Film, sound, television, audio, visual. British Kinematograph Sound and Television Society, 110-112 Victoria House, Vernon Place, London WCIB 4DJ, England.

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SMPTE Journal

International Technical and Engineering Society. The *SMPTE Journal* is published monthly and is the primary link between the Society and its members. Society of Motion Picture and Television Engineers, 595 West Hartsdale Avenue, White Plains, NY 10607. Telephone (914) 761-1100.

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